NOTICE

All drawings located at the end of the document.

Draft
Resource Conservation and Recovery Act Facility Investigation/ Remedial Investigation Report Operable Unit 3 (Offsite Areas)

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

Environmental Restoration

Volume I of III
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FIGURES

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ACRONYMS AND ABBREVIATIONS

AEC	United States Atomic Energy Commission
AOCs	Areas of Concern
ASTM	American Society of Testing and Materials
BCF	bioconcentration factor
BNAs	base neutral acids
Bq	Becquerel
BRA	Baseline Risk Assessment
BSCP	Background Soils Characterization Project
CDA	Colorado Department of Agriculture
CDOW	Colorado Division of Wildlife
CDPHE	Colorado Department of Public Health and Environment
CEARP	Comprehensive Environmental Assessment and Response Program
CEDE	Committed Effective Dose Equivalent
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CESC	Citizens' Environmental Sampling Committee
cfm	cubic feet per minute
cm	centimeter
HWA	Colorado Hazardous Waste Act
CLP	Contract Laboratory Program
CMS	Corrective Measures Study
COCs	Chemicals of Concern
COE	Corps of Engineers
CR	Concentration Ratio
CSM	Conceptual Site Model
CSU	Colorado State University
CT	Central Tendency (exposure)
CWQCC	Colorado Water Quality Control Commission
DOE	Department of Energy
DQA	Data Quality Assessment
DQO	Data Quality Objectives
DRCOG	Denver Regional Council of Governments
ECOC	Ecological Chemicals of Concern
EDE	Effective Dose Equivalent
EG&G	EG&G Rocky Flats
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ER	Environmental Restoration
ERA	Ecological Risk Assessment
ERDA	Energy Research and Development Administration
FDM	Fugitive Dust Model
FRICO	Farmers Reservoir and Irrigation Company
FS	Feasibility Study
ft	feet
FWS	U.S. Fish and Wildlife Service
GIS	Geographical Information System

g/m2	grams per square meter
GWR	Great Western Reservoir
HACH	Hardness and Alkalinity Test Kits
HAP	Health Advisory Panel
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IA/PA	Industrial Area/Protected Area
IAG	Interagency Agreement
ICRP	International Commission on Radiological Protection
IHSS	Individual Hazardous Substance Site
IHSS 199	Individual Hazardous Substance Site-contamination of land surface
IHSS 200	Individual Hazardous Substance Site-Great Western Reservoir
IHSS 201	Individual Hazardous Substance Site-Standley Lake
IHSS 202	Individual Hazardous Substance Site-Mower Reservoir
IM	Interim Measure
IRA	Interim Remedial Action
kg	kilogram
km	kilometer
LC50	Lethal Concentration 50% Mortality
LHSU	Lower Hydrostratigraphic Unit
LOAEL	Lowest Observed Adverse Effect Level
m	meter
MDA	Minimum Detectable Activity
MeV	Million electron volts
mg	microgram
MG	million gallons
mrad	millirad
mrad/d	millirad per day
mrem	millirem
MRI	Midwest Research Institute
MUSLE	Modified Universal Soil Loss Equation
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NOAEL	No Observable Adverse Effect Level
NPDES	National Pollution Discharge Elimination System
OU	Operable Unit
OU 3	Operable Unit 3
PARCC	Precision, Accuracy, Representativeness, Completeness, and Comparability
PCB	Polychlorinated Biphenyl
pCi	Picocurie
PCOCs	Potential Chemicals of Concern
PHE	Public Health Evaluation
PM-10	Particulate Matter, 10 microns or less
PPRGs	Programmatic Preliminary Remediation Goals
PRGs	Preliminary Remediation Goals
PVC	polyvinyl chloride

QA	Quality Assurance
QC	Quality Control
RAAMP	Radioactive Ambient Air Monitoring Program
RAOs	Remedial Action Objectives
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RME	Reasonable Maximum Exposure
SLDP	Standley Lake Diversion Project
SLPP	Standley Lake Protection Project
SOP	Standard Operating Procedure
TAL	Target Analyte List
TCL	Target Compound List
TDS	Total Dissolved Solids
TEDE	Total Effective Dose Equivalent
TM	Technical Memorandum
TOC	Total Organic Carbon
TSP	Total Suspended Particulate
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
UHSU	Upper Hydrostratigraphic Unit
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTL	Upper Tolerance Limit (hot measurement test)
VOC	Volatile Organic Compound
WQCC	Water Quality Control Commission

EXECUTIVE SUMMARY

The Operable Unit 3 (OU 3) (Offsite Areas) Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) Report contains the summation of twenty-five years of studies and investigations designed to assess the nature and extent of contamination from the U. S. Department of Energy (DOE) Rocky Flats Environmental Technology Site (Rocky Flats). The objective of the nature and extent assessment is to collect information necessary to determine the risk posed by contaminants released to the OU 3 offsite areas, and their impact on human health and the environment. The determination of this risk provides a basis for making remedial action or risk management decisions.

This executive summary is intended to provide information to the public in an accessible manner. Because OU 3 represents the offsite areas, it is expected that public interest will be high. It is for this reason that the executive summary of this report has been expanded and is more comprehensive than executive summaries of previous RI reports.

SITE DESCRIPTION

Rocky Flats is located on 6,535 acres of federal property in Jefferson County, Colorado, approximately 16 miles northwest of downtown Denver. The 385-acre main production facility is within the security-controlled area and is surrounded by a 6,150-acre buffer zone that delineates the site boundary (Figure 1-1).

Rocky Flats is part of a nationwide nuclear weapons complex that is owned by the DOE and is a contractor-operated facility. Prior to 1992, the mission of the facility was to support nuclear weapons research, development, and production. The facility fabricated components for these weapons from plutonium, uranium, beryllium, and stainless steel. In 1992, the production mission was suspended and the site was subsequently rededicated to a mission of environmental cleanup and technology development.

In 1991, an Interagency Agreement (IAG) was signed by the United States Environmental Protection Agency (EPA), the Colorado Department of Public Health and Environment (CDPHE), and the DOE. The IAG describes the process in which Individual Hazardous Substance Sites (IHSSs) at the site are investigated and eventually remediated. An IHSS is a location or area where a release of contamination into the environment is believed to have occurred. All the IHSSs at Rocky Flats collectively compose 16 OUs. The OU 3 RFI/RI and all activities performed under the IAG are consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), RCRA, the National Contingency Plan (NCP), and the Colorado Hazardous Waste Act (CHWA). OU 3 is unique among the 16 OUs because it is located outside of the site boundary. Studies within OU 3 are designed to assess the impact of contaminants that have been released onto offsite areas.

Operable Unit 3 is defined as simply the offsite areas. While this definition is inclusive of areas north, south, east, and west of the Rocky Flats boundary, a working definition of OU 3 was developed to envelop suspected contaminated areas and to focus the remedial investigation on areas where previous data have indicated the presence of measurable contamination (Figure 1-2). For practical purposes, OU 3 encompasses an approximately 38-square mile area north, south, and primarily east of Rocky Flats. The area west of Rocky Flats is generally considered to represent background conditions because it is upgradient from the prevalent wind direction, and upgradient with respect to groundwater and surface-water drainage patterns. For these reasons, the areas west of Rocky Flats are not generally considered to be part of OU 3. OU 3 consists of four IHSSs: IHSS 200, Great Western Reservoir; IHSS 201, Standley Lake; IHSS 202, Mower Reservoir; and IHSS 199, the surrounding surficial soils.

There were two events that represent the primary sources of contaminant release to OU 3. From 1958 to 1969, the 903 Pad was used as a storage site for 55-gallon drums containing plutonium-contaminated lathe coolant. Exposed to the elements, these drums corroded and subsequently leaked their contents onto the surrounding soils. Wind erosion and resuspension distributed these contaminated soils in a generally eastward trending plume that extended beyond the site boundary onto offsite areas east of Indiana Street. Efforts to mitigate this contaminant source involved the removal of contaminated soils at the 903 Pad, placement of an asphalt cap over the previous storage area, and deep disc plowing of soils immediately east of the Rocky Flats east gate.

The second significant event contributing to offsite contamination occurred from 1970 to 1973 in which sediments from the Walnut Creek A and B series detention ponds were released during a re-engineering project. These sediments were suspended during construction and subsequently flowed into Great Western Reservoir.

PREVIOUS ASSESSMENTS

Several soil and reservoir contamination studies have been undertaken to assess the impact of offsite contaminant releases. Although these studies have had many different sponsors, including DOE, EPA, CDPHE, various universities, municipalities, and individuals, the results have been similar.

The most pertinent work to assess the extent of offsite soil contamination began in 1970 with the work of Krey and Hardy (1970). Krey and Hardy sought to identify the primary sources of offsite contamination. They considered four potential contributors: the 1957 fire in Building 771, the 1969 fire in Building 776, chronic low-level stack effluent, and releases from leaking drums stored at the 903 Pad. Based on the particle size of the contaminated soil fraction, meteorological data, and Rocky Flats monitoring records, Krey and Hardy concluded that the majority of the plutonium released to IHSS 199 originated as windborne particulates from the 903 Pad. Subsequent studies (Seed et al. 1971; Loser and Tibbals, 1972; Illsley 1977 and 1979; Colorado Department of Health, 1977; Illsley and Hume, 1979; and CDPHE Health Advisory Panel, 1994) reinforced this conclusion. Krey and Hardy also attempted to define the areal distribution of plutonium from Rocky Flats. An iso-concentration map was published in their 1970 study that extended contours southeast into the cities of Arvada and Denver. This conclusion was drawn from a limited data set of 33 samples. Later studies sought to bring better definition to the extent of Rocky Flats contamination by increasing the number of samples and reducing the uncertainty of interpolating between data points.

In 1991, 47 samples were collected in what was formally known as the Jefferson County Remedy Acres (Remedy Lands). The Remedy Lands are 350 acres that were deeded to Jefferson County as partial settlement of a lawsuit filed in 1975. This area underwent remediation by deep disc plowing to bring plutonium levels down below 0.9 pCi/g (a special construction standard developed by CDPHE). The tilled areas are currently being re-vegetated. Plutonium levels in the untilled tracts remain slightly elevated above global fallout levels, which regionally are 0.038 pCi/g (DOE, 1995b). Background levels of radionuclides exist as either naturally occurring elements, or in the case of plutonium and americium, in the form of global fallout from atmospheric nuclear weapons testing. Additional details and an excellent summary of these historical studies can be found in the Final Past Remedy Report, Operable Unit No. 3 - IHSS 199 (DOE 1991b).

Studies of releases to the reservoirs also began in 1970 when the EPA conducted the first extensive sampling of the Great Western Reservoir bottom sediments (EPA, 1971). The results indicated that the reservoir sediments contain elevated plutonium in a layer approximately 2-inches thick. In this study, the highest concentrations were detected in the Walnut Creek inlet area and the central portions of the reservoir. A subsequent study found the highest concentrations of plutonium in the deepest portions of the reservoir (EPA, 1975). The EPA also concluded that the primary sources of contaminants to Great Western Reservoir could be attributed to early operational practices at Rocky Flats, a tritium release in 1973, reconstruction of the holding ponds from 1970 to 1973, and airborne transfer (primarily plutonium from the 903 Pad). Several additional studies were conducted in Great Western Reservoir which concluded that plutonium introduced into the reservoirs was adsorbed rapidly and essentially irreversibly onto the clay fraction of the sediments (CSU, 1974; Rockwell, 1985b). These studies also concluded that there was virtually no vertical migration of plutonium through the sediment column. This suggests that plutonium released into surface-waters is efficiently retained by the bottom sediments of both onsite retention ponds and offsite reservoirs and poses a minimal exposure threat. Extensive water sampling by the City of Broomfield and DOE confirm the immobility of plutonium in sediments. Studies by Rockwell and the City of Broomfield indicated that the highest plutonium levels in Great Western Reservoir are buried beneath 10 to 20 inches of sediment, due to continued sedimentation over time, further limiting the potential for exposure to these sediments (Rockwell, 1985b; City of Broomfield, 1992). Sedimentation rate studies by Rockwell and DOE were able to correlate the sediment horizons containing the highest plutonium levels to historical releases from the site (Rockwell, 1985b; DOE, 1994c). These studies indicate that since the implementation of mitigative measures such as the 903 Pad asphalt cap, the completion of the retention ponds, and the construction of the Broomfield Diversion Ditch in 1989, no releases have been recorded in the sediments of Great Western Reservoir. Even releases of very low levels of radionuclides would be retained in the sediment column and identified by the most recent sampling in OU 3.

The EPA studies in 1971 and 1973 also addressed plutonium in the sediments of Standley Lake. These studies concluded that there was no discernable contamination attributable to Rocky Flats. Subsequent studies (DOE, 1978; Battelle, 1981; Rockwell, 1984) indicated that the sediments of Standley Lake did contain levels of plutonium that were slightly elevated above global fallout levels, and that their presence could be attributed to the release from the 903 Pad. Extensive water sampling by the City of Westminster and DOE confirm the immobility of plutonium in the sediments for Standley Lake. Studies of fish in Standley Lake by CDPHE in 1989 found no radionuclides present in fish tissue samples but did detect contaminants such as insecticides and metals that were not unique to Rocky Flats.

Studies of Mower Reservoir have been sparse due to its limited use as an agricultural water supply. The EPA study sampled the sediments of Mower reservoir and concluded that plutonium activities were slightly elevated above background (EPA, 1971).

More details of the above investigations, and an excellent summary of these historical studies can be found in DOE (1991d).

Operable Unit 3 Remedial Investigation

While historical assessments have been confined to a specific media or reservoir, the OU 3 RI is the first study to integrate the assessment across soils, sediments, surface-water, groundwater, air, and ecological media. The OU 3 RI was designed to confirm many of the earlier studies by collocating data sampling points and performing statistical analyses to compare these newly collected data to some of the historical data sets. However, this RI was developed using a quality assurance program and data quality objectives for quantitatively determining risk to human health and the environment, and providing decisions regarding remediation and risk management. Much of the historical data collected prior to the OU 3 RI may be unsuitable for the purpose of quantitative risk assessments because the current quality assurance and quality control requirements were not in place. While past investigations focused primarily on the distribution of radionuclides, the OU 3 RI evaluated other potential contaminants that could be attributed to Rocky Flats. Additionally, the RI investigated all of the potentially contaminated media.

The OU 3 RI data collection began in the spring of 1992. Sampling was initiated for surficial and subsurface soils, stream and reservoir waters and sediments, groundwater, air, plants, small mammals, fish, and aquatic insects. The sampling program was implemented according to the field sampling plan included as part of the OU 3 Work Plan (DOE, 1992a). The work plan was developed jointly with the EPA, CDPHE, stakeholders, and DOE. Sample locations and methodologies were approved by these entities as part of this planning effort. Optimal sampling locations were selected for each medium to provide representative sampling throughout the OU.

Surface and Subsurface Soils

For the OU 3 RI, surficial soils from 61, 10-acre plots located throughout the OU were sampled for radionuclides (Figure 2-1). The sample locations were representative of the site conditions during the releases that could have deposited contaminants in the OU. Areas that appeared to have been subsequently disturbed were not sampled and another site was chosen. Additionally, sample locations were purposely biased to areas where contamination was known to exist. The results of the sampling effort confirmed that the highest levels of plutonium and americium could be found immediately east of Indiana Street near the east entrance of Rocky Flats. The highest level sampled in this area was for plutonium (2.95 pCi/g). Samples from the Remedy Lands taken in 1991 exhibited a maximum plutonium activity of 6.47 pCi/g. The 1991 Remedy Lands data set was included with the OU 3 RI data set because the plutonium levels in the Remedy Lands samples are generally higher than most of the OU 3 RI sample results. Combining the data sets results in a more conservative analysis. This data set followed EPA quality assurance requirements.

An evaluation of the sampling results concludes that plutonium and americium are the only chemicals of concern (COCs) for the human health risk assessment in surficial soils. The distribution of plutonium and americium in the surface soils is generally configured as a west to east trending plume with the 903 Pad serving as the primary source area. Radionuclide activities in the soils decreased with distance from Rocky Flats reaching background levels 2 to 3 miles from its east entrance (Figure 4-6A and Figure 4-6B).

To evaluate the presence, vertical extent, and activities of contaminants in subsurface soils, 11 trenches were excavated. In each trench, 10 samples were taken from ground surface to a depth of 96 cm at 3 cm intervals. Evaluation of the subsurface soils indicates that within 10 cm of the surface, the activities of plutonium and americium are at or below background levels. This rapid decrease in activity indicates that plutonium and americium are retained at the surface, generally considered to be the top 6 cm, and vertical migration is extremely limited. The same factors that limit the mobility of plutonium in sediments also limit the movement of plutonium in soils. Additional information regarding the distribution of radionuclides in the OU 3 soils can be found in Section 4.0 of this report.

Surface Water

A total of 52 surface-water samples were collected from 33 locations including the reservoirs (Standley Lake, Great Western Reservoir, and Mower Reservoir), and the drainages (Walnut Creek, Woman Creek, Dry Creek, Valley Ditch, Church Ditch, Coal Creek, and Big Dry Creek) (Figure 2-2). The surface-water sampling program also accounted for the routine monitoring performed by CDPHE, and the cities of Broomfield, Westminster, Thornton, and Northglenn. The OU 3 RI surface-water sampling plan took into account the historical and current sampling programs of the cities and state, and the historical surface-water data from the onsite effluent samplers. The sample analyses focused on water quality, dissolved and total metals, and dissolved and total radionuclides. Volatile organic compounds (VOCs) were added to the analyte list for Mower Reservoir because it had never before been evaluated for VOCs. Sample locations within the reservoirs were distributed so as to be representative of the conditions within each reservoir and to characterize the water quality.

Results of the surface-water sampling effort confirmed earlier evaluations that concluded that plutonium and americium in the surface-water of OU 3 are at or near background levels (Rockwell, 1981; Battelle, 1981; EPA, 1975). Radionuclide levels that were above background, were below risk-based screening levels that are developed to be protective of human health. Metals evaluated as part of the RI also occurred at background levels or below risk-based screening levels. VOCs in Mower Reservoir were not detected. Subsequent evaluation of the RI surface-water data determined that there are no COCs in the surface water that require the assessing of risk to human health. A more detailed explanation of surface-water evaluation is contained in Section 4.0, Nature and Extent.

Stream and Reservoir Sediments

Sediments were evaluated from the surface-water reservoirs and drainages listed above. A total of 128 surface-sediment samples were collected during the RI for OU 3, and 114 reservoir sediment samples were collected from Great Western Reservoir and Standley Lake in 1983/1984. Several of the RI sediment samples were collocated with the 1983/1984 sample locations to determine if the sampling and analysis methods and the results were comparable. These data sets were combined because it was determined that they were statistically comparable. In addition, subsurface reservoir sediments were sampled using gravity core samplers to identify subsurface zones of contamination, and to determine if vertical migration is occurring in the sediment column.

The results of this sampling concluded that the sediments of Great Western Reservoir are the most elevated with respect to plutonium. The maximum detected value (4.03 pCi/g) occurs beneath 18 inches of sediment. The maximum value in Mower Reservoir (1.11 pCi/g) is found in the subsurface at a depth of 4 inches. The maximum value in Standley Lake (0.38 pCi/g) is also buried beneath 18 inches of sediment. These results can be roughly correlated with the releases of the late 1960s and early 1970s. Low activities in the surface sediments indicate that since the recorded historical events, there have been no measurable releases recorded in the sediments. Reservoir sediments act like a tape recorder. Chemicals deposited in the reservoirs whether by windborne deposition, or by fluvial deposition, tend to be preserved in the sediments. Subsequent deposition buries these chemicals and thus a release event is recorded as a discrete sediment horizon with a particular contaminant that exceeds local background levels. Further evaluation of the subsurface sediment data reveals stable plutonium levels over time in the subsurface contaminated horizons. This is evidenced by comparing the subsurface-sediment plutonium activities from the RI with the plutonium activities in sediment cores from historical studies (DOE, 1994c). This comparison suggests that there is no vertical migration of plutonium in the sediment column and that contaminants are stabilized in discrete subsurface horizons.

In completing the evaluation of the sediment data, it was determined that plutonium-239, 240 was a COC with respect to human health in Great Western Reservoir. The impacts of this risk are further evaluated in the human health risk assessment. Surface-water releases in Walnut Creek during 1970-1973 probably influenced radionuclide levels in Great Western Reservoir more than any other reservoir in OU 3. The plutonium values in Great Western Reservoir are 10 times higher than those of Standley Lake. Risk associated with Great Western Reservoir represents the highest risk among all of the OU 3 reservoirs. More detail regarding the distribution of contaminants in the reservoirs and the risk posed by these contaminants can be found in Sections 4.0 and 6.0.

Groundwater

Two groundwater wells were installed downgradient of Great Western Reservoir and Standley Lake. These wells were installed to determine if plutonium and americium are migrating from the reservoirs via the groundwater. Comparison of the results from these wells with background values indicates that there are no contaminants present in the groundwater downgradient of the reservoirs, and that there is no indication that contaminants are migrating from the reservoirs via the groundwater. These results were expected because of the extremely low solubility of plutonium and americium in groundwater. Groundwater wells at the site boundary have not detected the presence of contaminants leaving the site via the groundwater pathway. Therefore, additional groundwater evaluation was not performed for the OU 3 RI.

Air

In this RI, air is considered a potentially contaminated media as well as a potential transport media. The information gathered during the RI is designed to characterize the potential for plutonium to be eroded from OU 3 soils and sediments. Two sources of data gathering were utilized to characterize this potential.

A wind tunnel study was performed in an attempt to quantify the erosion potential of the OU 3 soils and sediments. Test sites were located on the shores of Great Western Reservoir and Standley Lake, as well as the terrestrial sites in between. The objectives of the study were to determine under what conditions resuspension occurs, (i.e. what soil conditions, wind velocities, type of vegetative cover, and what is the resuspension rate or the emission rate of the soils and dry sediments). This information can be used to calculate exposure rates for determining human health risk. The results of the wind tunnel study determined that resuspension of soils and dry sediments is most likely to occur when the surface has been extensively disturbed. Test sites that exhibited the highest particle emissions, had been manually disturbed by raking and having a truck driven over them. These sites also lacked any vegetative cover. Emissions from these sites occurred after wind speeds reached 20 miles per hour for extensively disturbed dry sediment sites, and 27 miles per hour for extensively disturbed terrestrial sites. This is called the threshold velocity; the velocity at which resuspension begins. The threshold velocity increases as soil disturbance decreases. Undisturbed locations had threshold velocities of 61 miles per hour. Remedial action decisions should take into consideration the relative stability of the soils or sediments under undisturbed conditions.

The air pathway was also assessed through the installation of three ultra high-volume air samplers. These samplers were installed at locations representing potential residential and recreational receptors. The samplers intake air at a rate of 300 cubic feet per minute and will be used to supplement data from the existing Radioactive Ambient Air Monitoring Program (RAAMP) samplers, which have been in operation for several years at locations throughout Rocky Flats and surrounding community. It is anticipated that approximately 6 months of air monitoring data will be included in the Final RFI/RI report to be issued in early 1996. More details regarding the wind tunnel and air monitoring aspects of the RI may be found in Section 5.0 of this report.

Ecological Sampling

Ecological sampling was performed to determine the effects of contaminants on the OU 3 ecology, and to support an Ecological Risk Assessment (ERA). OU 3 is a potential receptor of material from Rocky Flats in that the onsite water sheds drain into the reservoirs, and the terrestrial areas of OU 3 represent zones of deposition for material that is transported aerially. Sampling focused on terrestrial organisms that may be directly exposed to the soils, and aquatic organisms that may be directly exposed to the sediments (i.e., benthic macroinvertebrates, bottom dwelling fish, and fish eggs). Ecological sampling was collocated with soil and sediment sampling locations to assess the effects of contaminants on ecological receptors and to evaluate the potential exposure. Evaluation of the data revealed that plutonium and americium are potential chemicals of concern (PCOCs) for ecological receptors. A preliminary risk characterization was conducted using a hazard quotient and hazard index method, and by compiling the information from the exposure and effects assessment for these chemicals. The results of the assessment concluded that the risk to either terrestrial or aquatic ecological receptors is minimal and within EPA guidelines. More detailed information may be found in Appendix B of this report.

Nature and Extent of Contamination

One of the functions of the RI was to determine the nature and extent of contamination. As discussed previously, evaluation of the sampling data indicates that plutonium and americium are COCs, based on human health, for the surface soils, and plutonium is a COC, based on human health, for the sediments of Great Western Reservoir. The COC selection process screened out all other chemicals based upon their occurrence relative to background levels, or based on their impacts on human health and the environment. Given these COCs, the RI identifies where in the environment the chemicals reside, and the extent of their distribution.

The most clearly defined contaminant distribution can be found in the reservoir sediments. Contaminants in the reservoirs are found in the sediments but not in the surface water. Their distribution in the sediment column appears to be restricted to discrete subsurface horizons where their occurrence can be correlated with the historical releases of the late 1960s and early 1970s. The sediment record does not indicate any recent releases, proven by the fact that plutonium levels in surface-sediments are considerably lower. As mentioned earlier, the reservoir sediments represent a relatively stable environment for plutonium. Data indicate that vertical migration of contaminants in the sediment column is not occurring. The reservoir sediments of OU 3 essentially represent the terminal receiving medium for plutonium in the watersheds. The extent of contamination is defined by the physical boundaries of the reservoir.

Defining the nature and extent of contamination in the surface soils of OU 3 is not quite as easy, in that the extent of contamination is not defined by physical or geographical boundaries. Rather the extent of contamination is defined by the depositional pattern of windborne particulates resuspended from the 903 Pad. Numerous investigations have sought to define the contaminant distribution in OU 3, each adding to the overall data set. As the OU 3 data set increases, the degree of uncertainty related to nature and extent determinations diminishes. The data set used in the OU 3 RI represents a compilation of much of the previously existing usable data combined with data collected exclusively for the OU 3 RI. Known as the exhaustive data set, 750 data points were used to determine the configuration and extent of the contaminant plume (Figure 4-6A and Figure 4-6B), (Litaor et al., 1995, Litaor and Allen, 1995). This data set was also used to evaluate the probability of exceedance for specific contaminant levels (Figure 4-7A and 4-7B). These figures illustrate that the contaminant plume has a well defined west to east configuration and that the southeastern component noted by Krey and Hardy (1970), either does not exist, or does not exert enough statistical influence to give the plume a southeastern vector. These figures also illustrate rapidly diminishing plutonium activities with distance from the 903 Pad source area. An extensive discussion of the statistical development of the nature and extent isocontours, and the associated probability maps can be found in Litaor et al. (1995), Appendix M, and in Section 4.0.

Baseline Risk Assessment

The ultimate goal of the RI is to evaluate the risk that Rocky Flats poses to human health and the environment, as the basis for remedial action or other risk management decisions. COCs must be determined to assess risks. The overall objective of the COC selection process is to identify the chemicals that contribute the most to human health risk and provide a focus for the human health risk assessment. The COCs for OU 3 are plutonium and americium in the surficial soils, and plutonium in the sediments of Great Western Reservoir. The human health risk assessment process is a conservative data evaluation methodology developed and approved by the EPA and CDPHE. The results of the risk assessment process are compared with regulatory guidelines that are developed for the purpose of protecting human health. The process consists of four main components: COC selection, exposure assessment, toxicity assessment, and risk characterization. These components combine to evaluate the conditions under which an individual is exposed to the COCs and the effects of that exposure. The methods for estimating risk incorporate numerous conservative assumptions so that any potential uncertainty may be biased conservatively. A detailed discussion of the risk assessment process can be found in Appendix A of this report. The exposure assessment is discussed in some detail here because it relates most directly to many of the assumptions made regarding future land use in OU 3.

The exposure assessment develops scenarios under which exposure may take place. It takes into consideration the exposure routes, potential receptors, durations of exposure, transport media, and exposure source areas. The conservative screen (DOE, 1995), a portion of the risk assessment methodology developed by CDPHE, identified areas of concern AOCs (Figures A5-3, A5-4). The AOCs represent areas within the OU that are most impacted by the selected COCs. The AOCs for OU 3 are located directly east of the Rocky Flats east gate and adjacent to Indiana Street within land areas that are currently zoned for open space and are tightly controlled by the cities of Broomfield and Westminster. This control effectively limits access and future development. Given the access control exercised by the current land owners, the most likely exposure is to a recreational user. This exposure scenario is quantitatively assessed in the human health risk assessment. Because future land use can be subject to change, a more conservative residential exposure scenario is also assessed in the human health risk assessment. While not currently plausible, the human health risk assessment assumes that a resident will occupy a drained Great Western Reservoir, and be exposed to the maximum plutonium levels found in the subsurface-sediments. A residential scenario was evaluated due to the uncertainty regarding the future utilization of Great Western Reservoir. It also assumes that deed restrictions held by the cities of Westminster and Broomfield limiting the use of land to open space in perpetuity, will be altered to allow residential development of the land directly east of Rocky Flats. Exposures are based on the inadvertent ingestion of surface soils and sediments, inhalation of resuspended surface soils and sediments, and external radiation exposure. The residential scenario also includes the ingestion of homegrown fruits and vegetables, and the ingestion of beef and milk from locally raised livestock. The residential scenario is more conservative because it assumes longer exposure durations instead of the infrequent exposures of a recreational user. While the assumptions needed to produce this scenario are conservative, the evaluation is useful for providing an upper limit on the potential risks, and helps to guide risk management decisions.

The results of the human health risk assessment can be compared with a risk range that is consistent with EPA guidelines (1 in 10,000 to 1 in 1,000,000) for being protective of human health. The risk assessment also estimates radiation dose to potentially exposed individuals. Known as the total effective dose equivalent, this value can be compared to annual radiation protection standards. Assessment of radiation dose compares these values with the DOE annual radiation dose limit for members of the public. The public dose limit is equal to 100 mrem/year for all routes of exposure.

For residential exposure to the surficial soils (IHSS 199), direct contact exposure to plutonium and americium is assumed to occur as a result of ingestion and inhalation. Indirect contact occurs through limited vegetable, beef, and milk consumption, and external radiation exposure. Using these exposure parameters, the highest identified activity in the soils, 6.47 pCi/g plutonium, equates to a risk of 3 in 1,000,000. Specifically, the additional risk posed by this level of plutonium in the soil may result in three additional incidences of cancer in a lifetime per one million people. The total effective dose equivalent is 0.026 mrem/year, which is well under the 100 mrem/year DOE annual dose limit for the general public. These values illustrate that under the most conservative residential exposure assumptions the risk in OU 3 from Rocky Flats contaminants is very low, and is below levels that warrant additional investigation or clean up.

For recreational exposure to surficial soils, the risk values are much lower because the exposure area is larger, the exposure durations are shorter, and exposure is limited to soil ingestion, inhalation, and external radiation exposure. The estimated excess lifetime cancer risk is 5 in 100,000,000 and the total effective dose equivalent is 0.003 mrem/year. The risk for recreational use of IHSS 199 is extremely low. Given the current deed restrictions held by the cities of Westminster and Broomfield, recreational open space is the most likely and appropriate utilization of IHSS 199.

As a conservative measure, a residential scenario was also developed for Great Western Reservoir (IHSS 200). In this scenario, it is assumed that the reservoir is drained and the reservoir basin is subsequently available for residential development. In this case, the exposure parameters for the sediments of this reservoir are the same as for the surficial soils of IHSS 199, and include sediment ingestion, inhalation, external radiation exposure, and ingestion of vegetables, beef, and milk. Excess cancer risk associated with these exposures is 9 in 10,000,000 with a total effective dose equivalent of 0.0065 mrem/year. This is within the EPA defined risk range consistent with being protective of human health, and under the DOE annual radiation dose limit of 100 mrem/year for the general public. By being conservative and evaluating residential exposure, the maximum risk is calculated for Great Western Reservoir. The human health risk assessment shows that even using the conservative assumption that a resident would inhabit the Great Western Reservoir basin and be exposed to subsurface soils and sediments, the risk is still within a range that is protective of human health. In other exposure scenarios, especially scenarios that maintain a water level in the reservoir, risk is well under levels of concern for human health. Using recreational conditions in which exposure is intermittent and of short duration, risk from exposure to the sediments drops to 1 in 100,000,000 , and the dose equivalent is 0.00014 mrem/year.

Understanding background radiation dose helps to put these numbers into perspective. The average member of the U.S. population receives an annual effective dose equivalent from ionizing radiation of approximately 350 mrem/year. This exposure is due to natural sources (such as radon gas and cosmic radiation), and radiation from natural materials (such as granite), and artificial sources (such as X-rays radiation), and radiation from natural materials (such as granite), and artificial sources (such as X-rays and nuclear medicine). Relative to the annual dose received from natural and artificial sources, the dose of less than 1 mrem/year due to contaminants in OU 3 is insignificant. A more detailed description and summary of the human health risk assessment can be found in Appendix A of this document.

Conclusion

The OU 3 RI is the culmination of over two decades of studies that attempt to define the extent of contamination in the offsite areas attributable to historical releases. The data set assembled for the nature and extent determination, and the risk assessment represents the largest and most comprehensive data set available for OU 3. Because of the exhaustive nature of the data set, remedial action and risk management decisions can be made with a relatively high degree of confidence.

Results of the RI indicate that the extent of contamination can be well defined as a west to east trending plume that is attributable to historic wind resuspension of contaminated soils from the 903 Pad. Risks associated with maximum concentrations in the surficial soils (IHSS 199) portion of this plume fall within the risk range that is consistent with EPA guidelines for the protection of human health (1 in 10,000 to 1 in 1,000,000). This risk was calculated using a conservative residential exposure scenario. The maximum risk calculated for IHSS 199 is 3 in 1,000,000. When the current and most likely future land use is considered, a recreational exposure scenario applies to IHSS 199. The results of the baseline risk assessment indicate that the maximum calculated risk for this scenario is 5 in 100,000,000. The NCP indicates that a risk level of 1 in 1,000,000 is a point of departure for making no action decisions, and that cumulative risks that exceed 1 in 10,000 warrant some type of remedial action. The calculated risk levels for OU 3 are below the NCP criteria, and provide the basis for determining that no remedial action is required.

Contamination in the reservoirs is contained within the reservoir sediments. The maximum activities are found in the subsurface-sediments in the deepest portions of Great Western Reservoir. Risk associated with exposure to these sediments also do not exceed the EPA public health guidelines.

The results of the OU 3 RI show that risks to the offsite neighbors of Rocky Flats do not exceed human health based standards set by the EPA and the CDPHE. Given the low risk values for the soils and Great Western Reservoir, and the most likely current and future land use scenarios, further investigation or remedial action is not warranted to be protective of human health and the environment. The next phase for OU 3 is the development of a Proposed Remedial Action Plan for public review and comment. This plan will provide the basis for an expected No Action Record of Decision.

1.0 INTRODUCTION

This document presents the results of the Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) of Operable Unit No. 3 (OU 3) at the U.S. Department of Energy (DOE) Rocky Flats Environmental Technology Site (Rocky Flats). In this document, the area within the boundaries of Rocky Flats is referred to as "the Site." OU 3 includes areas east of the site boundaries, specifically, four Individual Hazardous Substance Sites (IHSSs): IHSS 199 (Contamination of the Land's Surface), IHSS 200 (Great Western Reservoir), IHSS 201 (Standley Lake), and IHSS 202 (Mower Reservoir). The OU 3 RFI/RI is part of an ongoing DOE Environmental Restoration (ER) program of site characterizations, remedial investigations, feasibility studies, and remedial actions at Rocky Flats.

The ER Program is designed to investigate and, if necessary, remediate contaminated sites at DOE facilities, and involves five major activities:

- **Activity 1 - Installation Assessments** including preliminary assessments and site inspections to assess potential environmental concerns
- **Activity 2 - Remedial Investigations** including the development and implementation of field sampling programs to identify the magnitude and extent of contamination at specific sites, the evaluation of contaminant fate and mobility in the environment, and the performance of Baseline Risk Assessments (BRAs)
- **Activity 3 - Feasibility Studies** to evaluate remedial alternatives and develop remedial action plans, as necessary, to remediate sites identified during Activity 2
- **Activity 4 - Remedial Designs/Remedial Actions** including design and implementation of site-specific remedial actions selected on the basis of Activity 3
- **Activity 5 - Compliance and Verification** to monitor and assess the performance of remedial actions implemented under Activity 4 and document their efficacy.

Activity 1 has been completed for Rocky Flats (DOE, 1986). The OU 3 RFI/RI Report falls under Activity 2.

1.1 PURPOSE OF REPORT

The scope of the OU 3 RFI/RI is derived from the Interagency Agreement (IAG) between the U.S. Environmental Protection Agency (EPA), the Colorado Department of Public Health and Environment (CDPHE), and the DOE (EPA, 1991). The IAG describes the general response processes for IHSSs at Rocky Flats.

The purpose of the OU 3 RFI/RI report is to present the findings of the RFI/RI field investigation, including the nature and extent of contamination, contaminant fate and transport, and baseline risk assessment results. The objectives of the RFI/RI as detailed in the OU 3 Work Plan (DOE, 1992a) are as follows:

- Characterize physical features and ecological characteristics of OU 3
- Define sources of contamination
- Characterize the nature and extent of contamination at each IHSS in each medium that is a potential pathway
- Describe contaminant fate and transport
- Collect data to support the quantitative BRA to establish the baseline risk for the OU.

These objectives have been met and the results are summarized in this report. The work has been performed in accordance with the EPA-approved OU 3 RFI/RI Work Plan and addenda (DOE, 1992a). The BRA is presented in two appendices of this report: Appendix A is the Human Health Risk Assessment (HHRA) and Appendix B is the Ecological Risk Assessment (ERA).

1.2 REPORT ORGANIZATION

This report is organized as follows:

- **Section 1.0** provides introductory information, the purpose of the report, a general description of the IHSSs, history of Rocky Flats' activities affecting OU 3, and a summary of previous investigations performed in the vicinity of OU 3.
- **Section 2.0** presents a summary of the field investigations performed at OU 3, including the objectives of the field activity, summary of data collection procedures and sample locations, analyses requested, and refinements to the OU 3 Work Plan (DOE, 1992a) for each medium.
- **Section 3.0** describes the physical characteristics of OU 3, including surface features, demographics and land use, climate, soils, surface water hydrology, geology, hydrogeology, and ecology.
- **Section 4.0** presents the nature and extent of contamination for each medium and compares the OU 3 results to background/benchmark data sets.
- **Section 5.0** presents a discussion of contaminant fate and transport and describes potential routes of migration based on the OU 3 site conceptual model, and contaminant mobility and persistence.
- **Section 6.0** summarizes the findings of the BRA, which includes the HHRA and the ERA.
- **Section 7.0** presents a summary of the RFI/RI findings and conclusions including data limitations, additional data needs (if necessary), and recommended Remedial Action Objectives (RAOs).
- **Section 8.0** provides references.
- **Appendix A** presents the Human Health Risk Assessment.
- **Appendix B** presents the Ecological Risk Assessment.

- **Appendix C** presents a Summary of the Sample Collection and Analyses Performed.
- **Appendix D** presents the OU 3 Summary Statistics and Background Summary Statistics by Analyte.
- **Appendix E** presents a summary of the OU 3 Analytical Results.
- **Appendix F** presents the OU 3 Data Base Protocols.
- **Appendix G** presents the Quality Assurance Protocols and Results.
- **Appendix H** presents the Soil Trench Profiles for Radionuclides.
- **Appendix I** presents the Sediment Concentration Maps for Selected Metals.
- **Appendix J** presents the Sediment Core Profiles.
- **Appendix K** presents the Sediment Dating and Sedimentation Rates for OU 3.
- **Appendix L** presents the results of the PCB Sediment and Tissue Sampling.
- **Appendix M** presents Nature and Extent of Actinides in OU 3 Soils (Selected Papers)

1.3 SITE BACKGROUND

Rocky Flats is located approximately 16 miles (26 kilometers [km]) northwest of Denver and approximately 10 miles (16 km) south of Boulder (Figure 1-1). It is located on a high, arid plain at approximately 6,000 ft (1,800 m) above sea level and covers 6,550 acres (2,620 hectares) in northern Jefferson County, Colorado. Rocky Flats is part of a nationwide nuclear weapons complex owned by the DOE, whose production mission was suspended in 1992, and is undergoing environmental remediation and is in a long-term closure mode.

In past activities at Rocky Flats, components were fabricated for nuclear weapons from plutonium, uranium, beryllium, and stainless steel. Support activities have included chemical recovery and purification of recyclable transuranic radionuclides, and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics (DOE, 1988).

Main production facilities, constructed in 1951, are located near the center of Rocky Flats within a fenced security area of 348 acres. The remainder of the site contains limited support facilities and serves as a buffer zone to the main production areas. Operation of Rocky Flats fell under the administration of the U.S. Atomic Energy Commission (AEC) from 1951 until the AEC was dissolved in January 1975. Responsibility for the plant was then transferred to the Energy Research and Development Administration (ERDA), which was succeeded in 1977 by DOE. Dow Chemical USA was the prime operating contractor of the facility from 1951 until 1975.

Rockwell International was the prime operating contractor from 1975 until 1989, when EG&G assumed Rocky Flats operations. EG&G operated Rocky Flats from 1989 until July 1, 1995, when Kaiser-Hill assumed operations.

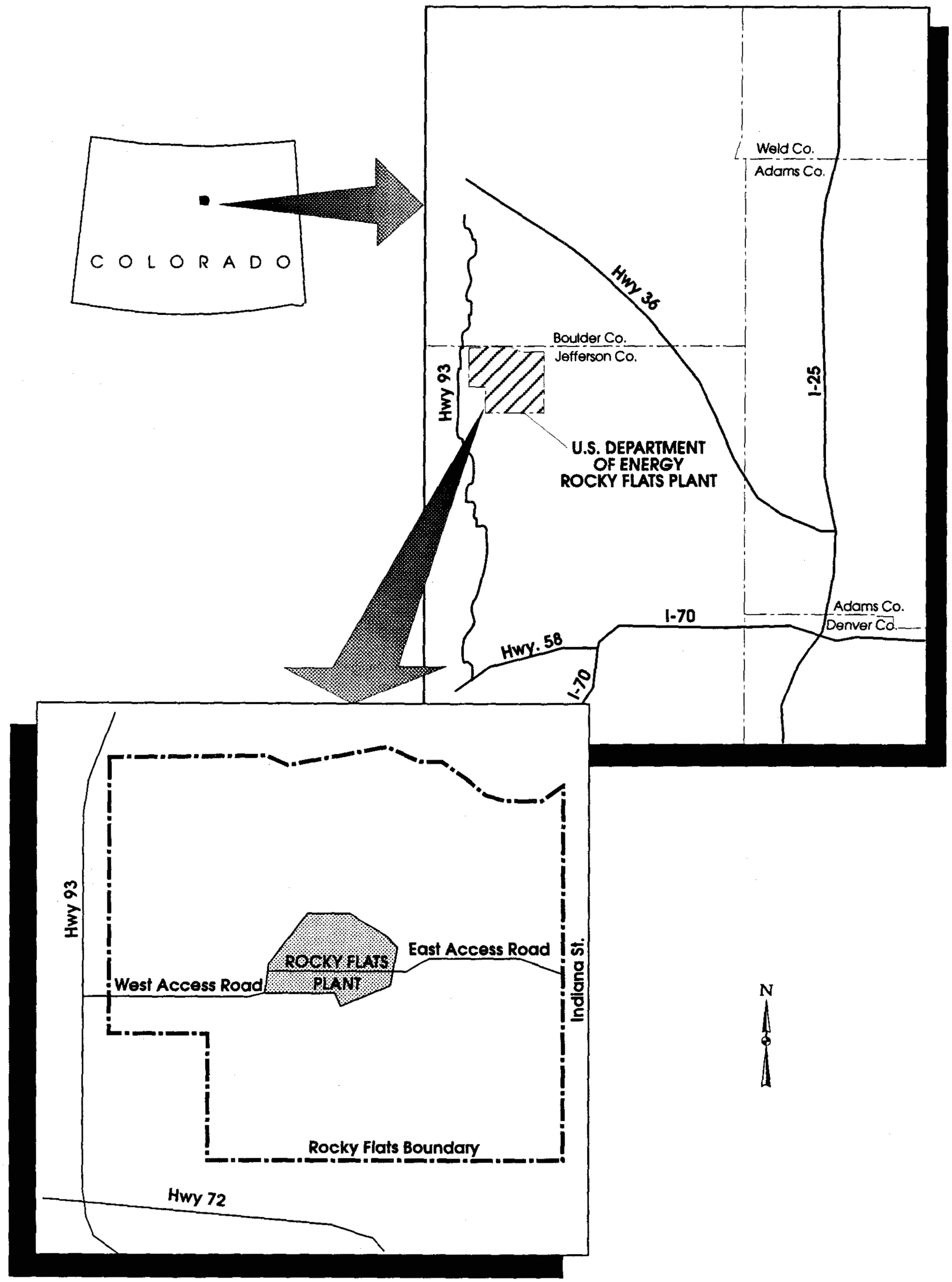

Figure 1-1 Location of Rocky Flats Environmental Technology Site

OU 3, located east of the buffer zone, is unique among Rocky Flats OUs because it is located outside the site boundaries. Based on historical data, recent sampling events, and the need for a manageable study area, a working definition for the OU 3 study area has been developed as shown in Figure 1-2. The designated OU 3 study area on Figure 1-2 is not intended to be a defined boundary, but rather a practical way to evaluate OU 3. The locations of each of the four IHSSs in OU 3 relative to Rocky Flats are shown in Figure 1-2 and are described in the following subsections.

1.3.1 IHSS 199 (Contamination of the Land's Surface)

IHSS 199, Contamination of the Land Surface, specifically includes soil contamination outside the boundaries of Rocky Flats. IHSS 199 includes all land located to the north, east, south, and west of the site boundaries, which could have potentially been impacted by historic Rocky Flats activities.

Several previous soil contamination investigations have been conducted in the vicinity of Rocky Flats to assess the impact and define the extent of contaminant releases to the offsite areas. The most pertinent study began in 1970 with the work of Krey and Hardy (1970). Krey and Hardy sought to identify the primary sources of offsite plutonium contamination and to define the areal distribution of contamination from Rocky Flats.

Krey and Hardy concluded that most of the plutonium release to IHSS 199 originated as windborne particulates from a former drum storage area (903 Pad) located in the southeastern portion of Rocky Flats. Subsequent studies in the vicinity of Rocky Flats (Seed et al., 1971; Loser and Tibbals, 1972; Illsley, 1977 and 1979; Colorado Department of Health, 1977; Illsley and Hume, 1979; and CDPHE Health Advisory Panel, 1994) reinforced this conclusion. Krey and Hardy published an iso-concentration map showing plutonium concentrations in surface soils relative to the site boundaries extending southeast into the cities of Arvada and Denver. The information illustrated on this map was based on a limited data set of 33 soil samples. Later studies have been able to better define the extent of offsite contamination by increasing the number of samples collected for analysis and utilizing improved analytical methods. Because the early studies presented different interpretations of the extent of contamination in Ou 3, the boundaries of OU 3 and IHSS 199 were left undefined. This allowed the OU 3 RFI/RI to proceed unconstrained by regulatory or artificial boundaries.

A comprehensive study of plutonium contamination in soils was performed in the vicinity of Rocky Flats for the OU 3 RFI/RI by Litaor et al. (1995). This study included data collected specifically for the investigation as well as the above-referenced historic data sets. The OU 3 RFI/RI surface soil data set was also incorporated into this study. The results of the comprehensive study indicate that the highest plutonium contamination is observed near the former 903 Pad drum storage area at Rocky Flats. Plutonium contamination decreases rapidly toward the eastern boundary of Rocky Flats. The 1995 study provides the most comprehensive appraisal of the content of plutonium contamination in OU 3 offered to date. Based upon the results of this study, the extent of the contaminant plume in OU 3 is well defined and the boundaries of OU3 and IHSS 199 can be refined if necessary.

Included within IHSS 199 are approximately 350 acres (142 hectares) of land east of Rocky Flats known as the Remedy Lands. The Remedy Lands are located on two tracts of land totaling 350 acres (142 hectares) in the southern half of Section 7 and the western half of Section 18, Township 2S, Range 69W. Both areas are just outside the eastern boundary, approximately 1.5 miles (2.4 km) east of the main production area of the plant (Figure 1-2). Both are generally downwind and downgradient of Rocky Flats. This remedy acreage was prescribed as a result of a 1975 lawsuit filed against Rockwell International Corporation, Dow Chemical Company, and the United States by the Church (McKay) plaintiffs and Great Western Venture partnership. The plaintiffs claimed that their land had been damaged by radioactive contaminants released from Rocky Flats. In December 1984, the plaintiffs and defendants reached a remedy settlement that called for ripping, plowing, and tilling affected soils to reduce plutonium concentrations. The agreement also stipulated the transfer of approximately 250 acres of land to Jefferson County and approximately 100 acres to the City of Broomfield. These lands are currently not open to the public (EG&G, 1991a). Approximately 120 acres of Jefferson County land has been remediated to date. At this writing, the City of Broomfield has not requested that Rocky Flats begin remediation on their affected acreage, but has excluded access of this acreage to the public (DOE, 1992b). The Jefferson County land (approximately 250 acres) was acquired by The City of Westminster in February 1995.

The settlement agreement for IHSS 199, history of litigation, and summary of remediation activities are presented in the OU 3 Work Plan (DOE, 1992a).

1.3.2 IHSS 200 (Great Western Reservoir)

IHSS 200 encompasses Great Western Reservoir, the associated drainages leading into and out of the reservoir, and their respective sediments (see Figure 1-2). Portions of Walnut Creek within the site boundaries will be investigated as OU 6 and are not included in IHSS 200.

Great Western Reservoir is located 1.5 miles east of the site's eastern boundary. Originally, the reservoir had a maximum depth of 42 feet and a storage capacity of 1,420 acre-feet. In 1955, the Turnpike Land Company purchased the reservoir and established the Broomfield Heights Mutual Service Association, which owned and operated water and sewer utilities for the Broomfield Heights development. In 1958, the reservoir was enlarged to its current storage capacity of 3,250 acre-feet (1.06 billion gallons) and is now approximately 60 feet deep (Schnoor, 1991). In 1962, the City of Broomfield bought the water and sewer services from the Turnpike Land Company, and in 1971 fenced the area around Great Western Reservoir to prevent public access (CDPHE, 1992).

The reservoir previously received surface water runoff from Clear Creek through Lower Church Ditch; from Coal Creek through McKay Ditch; and directly from Upper Church Ditch. Prior to construction of a diversion ditch in 1989, water from Walnut Creek's north and south branches flowed from Rocky Flats directly into Great Western Reservoir. Flows from Walnut Creek are now treated at Rocky Flats and are diverted south around Great Western Reservoir into the drainage ditch below the reservoir's outlet (Figure 1-2). This diversion, called the Broomfield Diversion Ditch, or Great Western Reservoir Diversion Ditch, prevents treated surface water originating at Rocky Flats from reaching Great Western Reservoir (EG&G, 1991a).

Since 1955, Great Western Reservoir has been the primary drinking water source for the City of Broomfield; currently receiving 60 percent of its water supply from Great Western Reservoir and 40 percent from the City of Denver. The City of Broomfield operates a water treatment facility immediately downstream from Great Western Reservoir, which supplies drinking water to approximately 28,000 persons (Broomfield, 1993). Water quality in Great Western Reservoir and the Walnut Creek drainage is routinely monitored by DOE, the City of Broomfield, and the CDPHE. The City of Broomfield and CDPHE collect samples at the water treatment facility and below the reservoir dam (CDPHE, 1990a). Great Western Reservoir has met and continues to meet all federal and state drinking water standards (CDPHE, 1990a).

Because of public concerns associated with historical drainage impacts from Rocky Flats to Great Western Reservoir, the DOE is planning to supply the residents of Broomfield with a new source of water from nearby Carter Lake. In addition, construction of the Broomfield Diversion Ditch isolates Great Western Reservoir from the north and south branches of Walnut Creek. Broomfield residents will continue to receive their water from Great Western Reservoir and the City of Denver until the Carter Lake pipeline project is completed in 1995 (Broomfield, 1993). Subsection 1.3.7 presents additional information on the Great Western Reservoir Project.

1.3.3 IHSS 201 (Standley Lake)

IHSS 201 includes Standley Lake, the associated drainages flowing into and out of the reservoir, and their associated sediments. Portions of Woman Creek within the boundaries of Rocky Flats are being investigated as part of OU 5 and are not included in IHSS 201. Standley Lake is a large reservoir located approximately 2 miles (3.2 km) southeast of the site's eastern boundary in Sections 16, 17, 20, 21, 22, and 28, T2S R69W. The normal capacity for Standley Lake is 43,000 acre-feet (5,300 hectare-meters) and its surface area is approximately 1,200 acres (DOE, 1992d). Although approximately 96 percent of Standley Lake's water originates as snowmelt from Clear Creek (not part of the OU 3 study area) via irrigation ditches (Farmer's Highline, Croke, and Church Ditches), some water does come from Woman Creek, Smart Ditch, and Upper Big Dry Creek. The water from these sources consists of both in-basin natural runoff and water that is diverted from Coal Creek, which lies to the west of Woman Creek and Upper Big Dry Creek.

Woman Creek runs just south of the Rocky Flats industrial area (Figure 1-2), through the buffer zone (DOE, 1992d). Recently, the DOE established a surface water control system to prevent runoff from reaching Standley Lake. Currently, only surface runoff from the buffer zone and natural groundwater seepage flow into the Woman Creek drainage areas within the site boundaries (DOE, 1992d). From 1914 to 1966, water from Standley Lake was used only for irrigation. However, water from Standley Lake is now divided between residential use by the following three municipalities and the Farmer's Reservoir and Irrigation Company (FRICO):

- The City of Westminster owns 37.3 percent of Standley Lake Division shares
- The City of Thornton owns 13.3 percent of Standley Lake Division shares
- The City of Northglenn owns 17.7 percent of Standley Lake Division shares
- FRICO owns 31.7 percent of Standley Lake Division shares

More than 180,000 people within the cities of Westminster, Thornton, Northglenn, and Federal Heights receive their primary drinking water from Standley Lake Reservoir (DOE 1992c). According to CDPHE (1990b), Standley Lake continues to meet all federal and state drinking water standards. FRICO's water is transported through irrigation ditches to agricultural areas located northeast of the lake, primarily between Broomfield and Fort Lupton, Colorado (Tipton, 1989).

1.3.4 IHSS 202 (Mower Reservoir)

IHSS 202 encompasses Mower Reservoir and the reaches of the irrigation ditch that feed the reservoir from Woman Creek located east of the site boundary (Figure 1-2). Portions of the irrigation ditch within the site boundaries of Rocky Flats are part of OU 5 and are not included in IHSS 202.

Mower Reservoir is located approximately 1.5 miles southeast of Rocky Flats (and approximately 1,400 feet from the eastern site buffer zone boundary). The water rights of Mower Reservoir, an agricultural resource, are privately owned by a local farmer. The associated water rights decree for Mower Reservoir states that water from the reservoir was first diverted for irrigation in 1872. The land surrounding the reservoir is owned by Jefferson County Open Space. Mower Reservoir is used for irrigation of pasture land and water for livestock. The reservoir is fed by Woman Creek via Mower ditch, an irrigation ditch that originates within the site boundary. Mower Reservoir covers approximately 9 acres (3.6 hectares) of surface area and is roughly 5 to 10 feet deep at its deepest point (DOE, 1992b). Outflow from Mower Reservoir flows southeast from the reservoir, eventually discharging to Standley Lake.

1.3.5 History of Plant Activities Affecting OU 3

Rocky Flats is part of a nationwide nuclear weapons complex owned by the DOE. Components for nuclear weapons were fabricated from plutonium, uranium, beryllium, and stainless steel. Associated support activities included chemical recovery and purification of recyclable transuranic radionuclides, and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics (DOE, 1988).

Both radioactive and nonradioactive wastes were generated during component fabrication. Current waste-handling practices involve onsite and offsite recycling of hazardous materials, onsite storage of hazardous and radioactive mixed wastes, and offsite disposal of solid radioactive materials at another DOE facility. In the past, both storage and disposal of hazardous and radioactive wastes occurred onsite. The preliminary assessment performed under the ER Program identified some of the past onsite storage and disposal locations as potential sources of environmental contamination (DOE, 1986).

In 1992, ChemRisk prepared a report for the CDPHE titled *Reconstruction of Historical Rocky Flats Operations and Identification of Release Points* (CDPHE, 1992). One of the objectives of the report was to document the history of the Rocky Flats Plant relative to offsite releases. A second objective was to identify release points for the materials of concern from routine and nonroutine (accidental) operations. The report concluded that "extensive reviews failed to identify any historical evidence of significant intentional controlled routine releases of radionuclides from the plant to the offsite environment". The report also states that:

> The review of historical accidents and incidents at the plant site led to the identification of voluminous amounts of information documenting numerous small fires, spills, injuries, and property damage. However, none of the documentation indicated the occurrence of any previously unreported major events potentially impacting the offsite public. Major events of potential interest are those that were studied and publicized following the 1969 fire (page 258).

The following subsections describe the historical operations that may potentially affect the IHSSs of OU 3.

IHSS 199

A study performed by Krey and Hardy (1970) sought, among other goals, to identify onsite sources of the plutonium found in offsite soils. These investigations focused on four onsite sources:

1. A September 11, 1957 fire in Building 771 (Dow, 1973).

2. A May 11, 1969 fire in Building 776 (CCEI, 1970).

3. Leaking plutonium-contaminated lathe coolant at the 903 Pad, a drum storage area in the southeastern part of Rocky Flats' main production area.

4. Chronic low-level stack effluent.

Based on the particle size of the contaminated soil fraction, meteorological data, and Rocky Flats monitoring records, the Krey and Hardy investigation concluded that the great majority of the plutonium at IHSS 199 originated as windblown particulate from the 903 Pad, and largely dismissed the contributions of the 1957 and 1969 fires and chronic stack emissions. Contamination at the 903 Pad resulted from 55-gallon drums of plutonium-contaminated lathe coolant that corroded and leaked over a 10-year period starting in 1958. The contaminated surface soils were excavated and the 903 Pad area was capped with asphalt in November 1969, effectively eliminating it as a direct source of contamination to IHSS 199. Numerous other investigations focusing on plutonium in the offsite soils since the Krey and Hardy study have reinforced the conclusion that the 903 Pad was the primary source of offsite soil plutonium contamination from Rocky Flats (Dow, 1971; Dow 1972; CDPHE, 1977; Rockwell, 1979a; Rockwell, 1979b). Another conclusion from the ChemRisk report is that: "of all plutonium accidents identified, the 903 Pad and the 1957 fire appear to have the greatest potential for offsite impacts to the public" (CDPHE, 1992).

IHSS 200

From the opening of Rocky Flats in 1952 through approximately 1979, water containing decontaminated process and laundry effluent was discharged through the B-series ponds to South Walnut Creek (DOE, 1988; Dow, 1973). Cooling tower blowdown and treatment system steam condensate were discharged to the A-series ponds, which feed into North Walnut Creek. These effluents were discharged in accordance with past internal guidelines (in particular, AEC guidelines) and, increasingly during the past two decades, with State of Colorado and Federal pollution discharge regulations. The effluents contained metals, radionuclides, and other inorganic ions (especially nitrate) within concentration limits considered acceptable at the time. Radionuclides and metals from these discharges accumulated in varying amounts in the sediments of the holding ponds, Walnut Creek, and Great Western Reservoir (DOE, 1980a). The EPA (1975) concluded that historic releases of radioactive contaminants from Rocky Flats to Great Western Reservoir resulted primarily from the following activities:

- Early operational practices at the plant (1950s and 1960s).

- Reconstruction of the holding ponds between 1970 to 1973, which resuspended pond sediments and released some of this material to Great Western Reservoir.

- A 1973 tritium release from Rocky Flats.

- Airborne transport of radionuclides (primarily plutonium) to offsite areas.

Available data from onsite OUs, particularly OU 6 (Walnut Creek Drainage), suggest that contaminants other than plutonium could conceivably have impacted Great Western Reservoir through surface-water transport from Rocky Flats. Leakage from the solar evaporation ponds is known to have contaminated groundwater and surface water in the Walnut Creek drainage, primarily with nitrate and other inorganic ions. Inorganic ions, nonradioactive metals, volatile organic compounds (VOCs), and uranium have been detected in the Walnut Creek holding ponds. Herbicides that have been applied in the past at various Rocky Flats locations have also been detected in Rocky Flats surface water. However, based on the preliminary conceptual model presented in the OU 3 Work Plan, evaluation of the fate and mobility of chemicals associated with Rocky Flats activities, and evaluations of historical data (including City of Broomfield and CDPHE data) and Rocky Flats environmental monitoring data, the surface water and sediment samples for IHSS 200 were only analyzed for radionuclides (including tritium), metals, and water quality parameters (surface water).

IHSS 201

Radioactive materials released from Rocky Flats may have been transported to Standley Lake through surface water (primarily in suspended sediments) and/or airborne particulate (fugitive dust). Between 1952 and 1973, water treatment facility filter backwash was discharged into Pond C-1, which discharges into Woman Creek (Rockwell, 1988a). At present, only surface runoff from the buffer zone and natural groundwater seepage flow into the Woman Creek drainage within the site boundary (Dow et al., 1971 to present).

Prospective contaminant sources, excluding plutonium in Standley Lake (particularly VOCs and uranium), exist in OU 1 (881 Hillside) and OU 2 (903 Pad, Mound, and East Trenches). Herbicides have also been detected in Rocky Flats surface water. However, based on the preliminary conceptual model presented in the OU 3 Work Plan, evaluations of the fate and mobility of VOCs and herbicides, and evaluations of Rocky Flats historical data (including City of Broomfield and CDPHE data) and environmental data, the surface water and sediment samples for IHSS 201 were only analyzed for radionuclides, metals, and water quality parameters.

IHSS 202

Rocky Flats-derived contaminants in Mower Reservoir have been transported primarily as airborne particulates, and to a lesser degree, by surface water through the Woman Creek drainage, which may have also contributed to plutonium concentrations in Standley Lake sediments. Surface water and sediment samples collected for IHSS 202 were analyzed for radionuclides, metals, and water quality parameters. IHSS 202 samples were also analyzed for VOCs.

1.3.6 Summary of Previous and Ongoing Investigations

Various studies have been conducted at and around Rocky Flats to characterize environmental media and assess the nature and extent of contamination in the environment. Previous investigations pertinent to OU 3 include the Site Environmental Monitoring and the historical investigations. Historical data for the IHSSs included in OU 3 have been reviewed and summarized in the *Final Past Remedy Report Operable Unit No. 3-IHSS 199* (DOE, 1991b) and in the *Historical Information Summary and Preliminary Health Risk Assessment Operable Unit No. 3-IHSS 200-202* (DOE, 1991d). Table 1-1 summarizes previous investigations that were reviewed in the Past Remedy Report and the Historical Information Summary and Preliminary Health Risk Assessment document. These findings are summarized in the following subsections. Results of the pertinent historical data specific to each IHSS are included in Section 4.0, Nature and Extent of Contamination, as appropriate.

Radiological and nonradiological environmental monitoring of effluent air, ambient air, surface water, groundwater, tap water, stream sediments, and soil is performed routinely at onsite and offsite locations. Results from these monitoring programs are published monthly and/or annually in Rocky Flats environmental monitoring reports (Dow et al., 1971 to present). Ambient air, soil, and surface water quality are also monitored in locations around Rocky Flats by the CDPHE and by cities utilizing Great

Table 1-1
Summary of Previous Investigations in the Vicinity of OU 3

Soils (IHSS 199)

"Plutonium in Soil Around the Rocky Flats Plant," by P. W. Krey and E. P. Hardy, 1 August 1970.

"Committee Evaluation of Plutonium Levels in Soil Within and Surrounding USAEC Installation at Rocky Flats, Colorado." by J. R. Seed et al., 9 July 1971.

"Soil Sampling East of Indiana Avenue," by R. W. Loser and R. L. Tibbals, 29 November 1972.

"Results of Special Soil Samples Collected Adjacent to the Rocky Flats Plant Site," by C. T. Illsley, 7 September 1977 (revised 30 November 1979).

"Radioactive Soil Contamination (Cesium-137 and Plutonium) in the Environment Near the Rocky Flats Nuclear Weapons Plant," by CDPHE, September 1977.

"Plutonium Concentrations in Soil on Lands Adjacent to the Rocky Flats Plant," by C. T. Illsley and M. W. Hume, 16 March 1979.

"Disclosure to the City of Broomfield," by Rockwell International, 22 January 1985.

"Soil Sample Collection and Analysis for Plutonium on Lands Adjacent to Great Western, Reservoir for the City of Broomfield," by C. T. Illsley, 15 January 1987.

"Remedial Action Program on Jefferson County Open Space Land in Section 7, T2S, R69W, South of Great Western Reservoir," by C. T. Illsley, 15 October 1987.

"Rocky Flats Surface Soil Survey, 1970-1989," by CDPHE, February 1990.

"Contamination of Surface Soil in Colorado by Plutonium, 1970-1989: Summary and Comparison of Plutonium Concentrations in Soil in the Rocky Flats Plant Vicinity and Eastern Colorado," by R.W. Terry, CDPHE, April 1991.

"Standley Lake Protection Project, Results of Soil Sampling Along the Potential Interceptor Canal," City of Westminster, 1991.

Area of Concern Report for OU 3, by DOE, September 1993.

Great Western Reservoir (IHSS 200)

"Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Golden, Colorado, 1970," by EPA, April 1971.

"Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Colorado, 1970, Part II," by EPA, December 1973.

"Plutonium Levels in the Sediment of Area Impoundment Environs of the Rocky Flats Plutonium Plant, Colorado," by EPA, February 1975.

"Survey of Reservoir Sediments," by Dow Chemical, August 1974.

"Radionuclide Concentrations in Reservoirs, Streams and Domestic Waters Near the Rocky Flats Installation," by Battelle PNL, April 1981.

"Great Western Reservoir Spillway Sediment Sampling Program Phase I Report," by Rockwell International, May 1979.

"Great Western Reservoir Spillway Sediment Sampling Program Phase II Report," by Rockwell International, August 1980.

"Great Western Reservoir Sediment Cores," by Rockwell International, February 1985.

Table 1-1 (continued)
Summary of Previous Investigations in the Vicinity of OU 3

Standley Lake (IHSS 201)

"Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Golden, Colorado, 1970," by EPA, April 1971.

"Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Colorado, 1970, Part II," by EPA, December 1973.

"Plutonium Levels in the Sediment of Area Impoundment Environs of the Rocky Flats Plutonium Plant–Colorado," by EPA, February 1975.

"Survey of Reservoir Sediments," by Dow Chemical, August 1974.

"Radionuclide Concentrations in Reservoirs, Streams and Domestic Waters Near the Rocky Flats Installation," by Battelle PNL, April 1981.

"Time Pattern of Offsite Plutonium Contamination from Rocky Flats Plant by Lake Sediment Analyses," by DOE, July 1978.

"Standley Lake Water Quality Study for the City of Thornton and City of Westminster," Arber Associates, December 1982.

"Standley Lake Sediment Sample Collection Summary," by Rockwell International, September 1984.

"Standley Lake Fish Toxics Monitoring Report," by CDPHE, January 1990.

"Draft Environmental Assessment Standley Lake Diversion Project," Standley Lake Cities, January 1992.

"Methods of Data Collection and Water–Quality Data for Standley Lake, Jefferson County, Colorado, 1989–1990." USGS Open–File Report 92–44.

Mower Reservoir (IHSS 202)

No known previous investigations have occurred for Mower Reservoir.

Western Reservoir and Standley Lake as municipal water supplies. The following information about these programs is taken primarily from the 1993 Site Environmental Monitoring Report (DOE, 1994a).

Ambient Air Monitoring

A network of continuously operating ambient air samplers is maintained on and in the vicinity of Rocky Flats. These samplers trap influent particulate on a filter element, and plutonium analysis is done. Specific information regarding sampler types and locations, analytical protocols, and analytical results have been summarized since 1971 in Rocky Flats annual environmental monitoring reports (Dow et al., 1971 to present). In 1993, there were 46 samplers in the ambient air sampling network, of which 21 are located on Rocky Flats, 14 are located along the site boundary, and 11 are located within nearby communities (see Figures 1-3 and 1-4). Rocky Flats has conducted onsite ambient air monitoring since the plant opened in 1951. The original network of low-volume (approximately 2 cubic feet per minute [cfm]) air samplers was upgraded in 1974 and 1975 to the high-volume (approximately 25 cfm) samplers currently in use. High-volume, offsite samplers, located within nearby communities, were added to the network at the time of this upgrade.

Sampling and analytical protocols have varied throughout the history of the ambient air monitoring program. Plutonium analysis of selected ambient air samples began in 1975; before this, onsite ambient air samples were analyzed for total long-lived alpha radiation only. Under the current protocol, samples are collected biweekly and analyzed for plutonium-239, -240. Since December 1990, samples from the site perimeter and nearby communities are collected biweekly and composited into single monthly samples from each sample station. In addition, the CDPHE maintains offsite air samplers for measuring plutonium concentration in ambient air in the vicinity of Rocky Flats (CDPHE, 1970 to present). These samples are analyzed for gross alpha and gross beta radiation in addition to plutonium.

Starting in the early 1980s, Rocky Flats conducted a program of onsite monitoring for EPA criteria pollutants (total suspended particulate, ozone, sulfur dioxide, carbon monoxide, nitrogen dioxide, and lead) utilizing a mobile ambient air monitoring unit. This mobile unit was replaced in mid-1986 with a permanent monitoring station, which is located just inside the east gate. Starting in 1989, this program was scaled back to include total suspended particulates and respirable particle fraction (those particles smaller than or equal to 10 microns in size) only.

In 1976, nine ambient air monitoring stations were installed by the Rocky Flats at and near IHSS 199 acreage, which was the subject of a lawsuit by owners of land adjacent to the plant. These stations were operated from November 1976 through July 1978 specifically to collect monthly data for airborne plutonium concentrations in support of answering the lawsuit. It was determined in 1978 that data collected from the lawsuit-specific stations did not significantly differ from data collected from nearby ambient-air program samplers, and the lawsuit-specific stations were, therefore, removed.

To supplement data obtained from permanent stations downwind of the acreage, airborne plutonium concentrations were monitored by Rocky Flats immediately downwind of the Remedy Lands. A tabulation of the 1987 remedy-specific monitoring data is included in Rockwell (1988b). A summary of average annual plutonium concentrations from selected ambient-air monitoring stations near the Remedy Lands during the period of remedial activity (1985 to 1988) is provided in Rockwell (1989a).

In 1993, the mean plutonium concentration for both the perimeter samplers and community samplers was 2.39×10^{-18} microcuries per milliliter (μCi/ml) (5.5×10^{-8} bequerels per cubic meter [Bq/m^3]) and

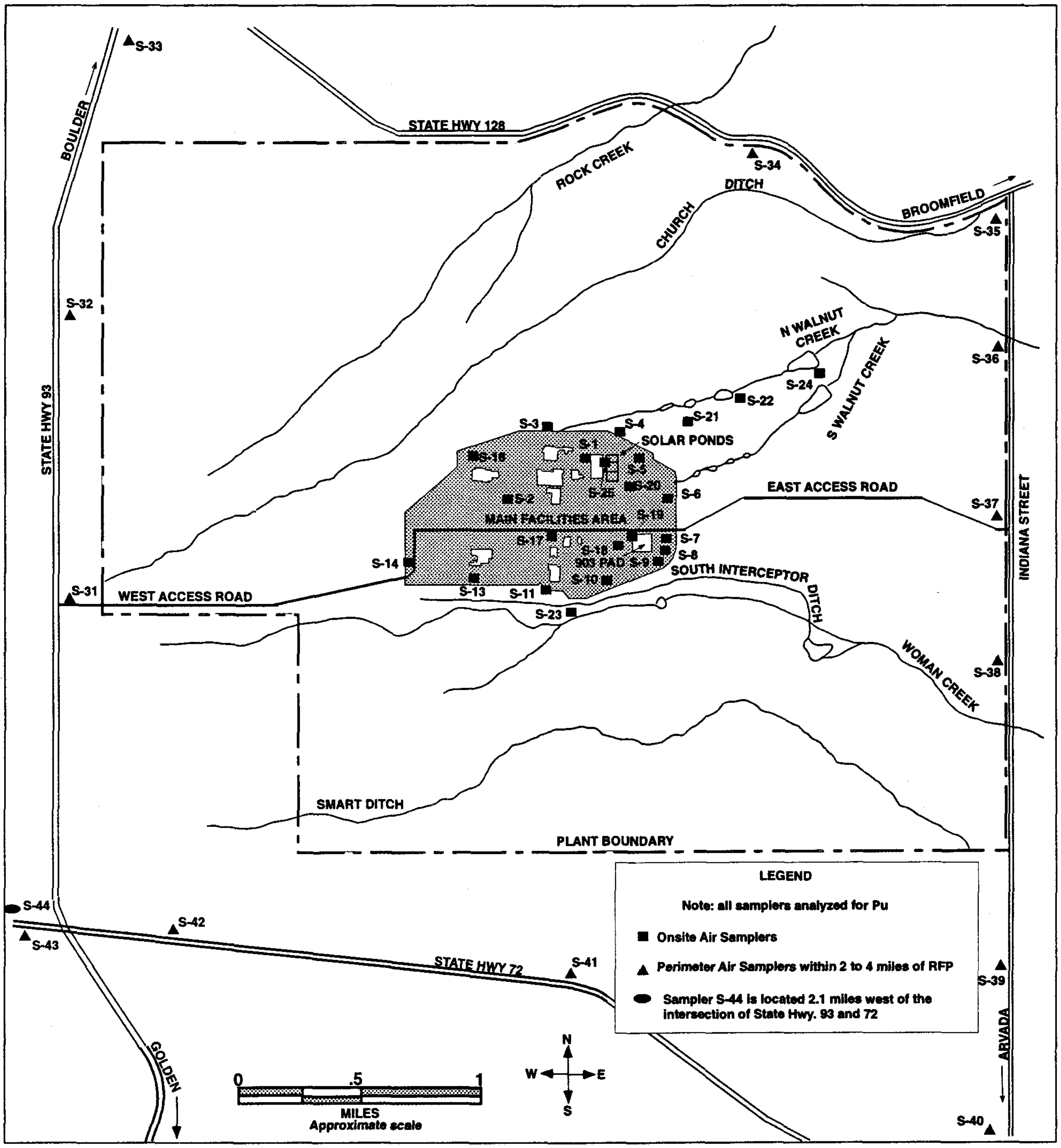

Figure 1-3 1993 Onsite and Perimeter Air Samplers
Source: EG&G, 1994c

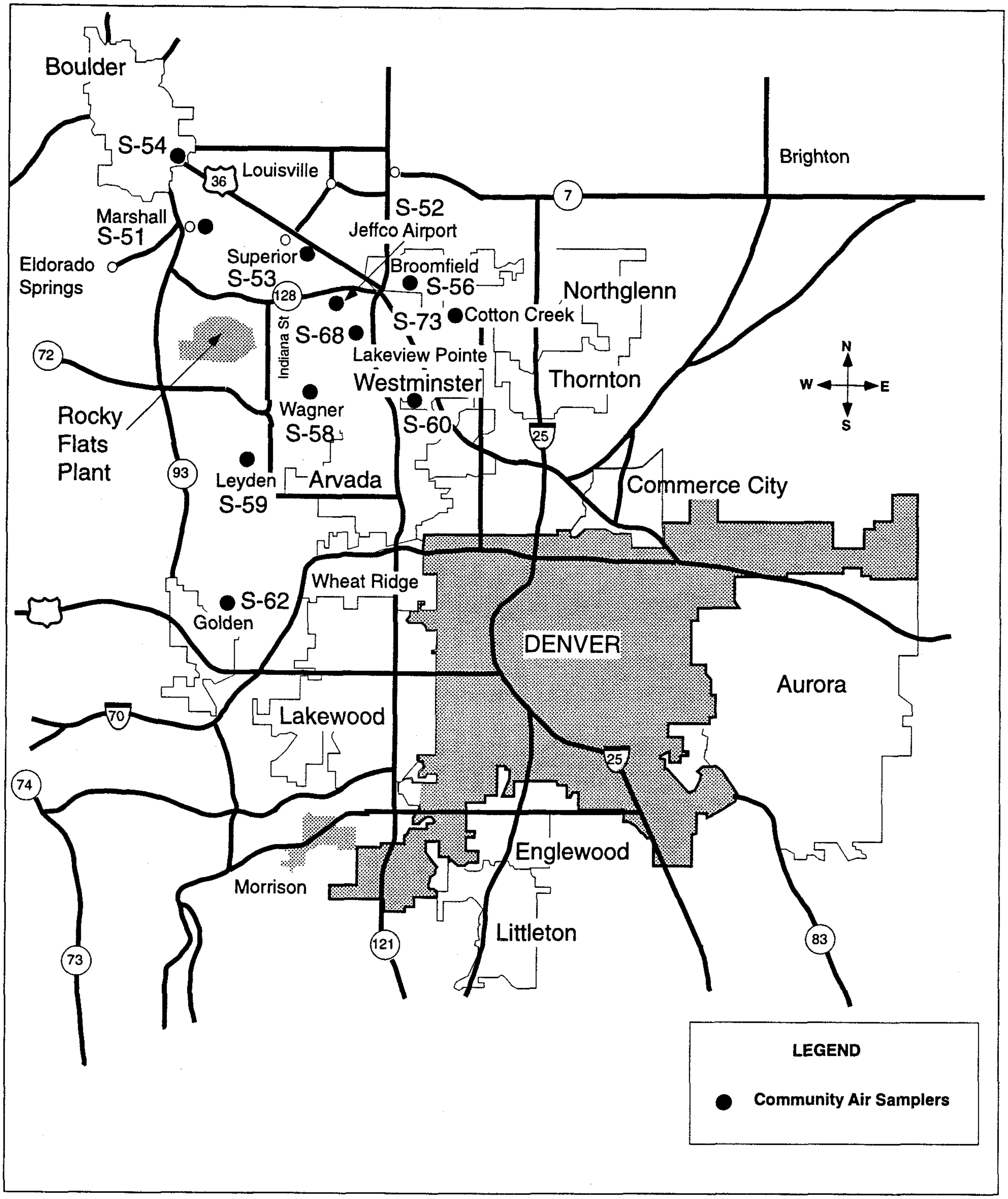

Figure 1-4 1993 Community Air Samplers
(from EG&G, 1994c)

1.20 x 10^{-18} µCi/ml (3.7 x 10-8 Bq/m^3), respectively. These values represent 0.008 and 0.006 respectively of the protection guideline for offsite residuals (the derived concentration guide is for inhalation of Class W plutonium by members of the public and is 2 x 10^{-14} µCi/ml (7.4 x 10^{-7} Bq/l). The protection guideline for members of the public is applicable for offsite locations and is based on calculated radiation doses (EG&G, 1994a).

In addition to the radiological monitoring, ambient-air monitoring for nonradioactive constituents was conducted in 1993 for total suspended particulate (TSP) and respirable particulates (less than or equal to 10 micrometers in diameter, PM-10). The highest TSP value recorded in 1993 (24-hour sample) was 90.0 micrograms per cubic meter (µg/m^3) (35 percent of the former TSP 24-hour primary standard), and the annual geometric mean value was 48.6 µg/m^3 (65 percent of former TSP primary annual geometric mean standard). The observed 24-hour maximum for the PM-10 sampler was 51.9 µg/m^3 (34.6 percent of the primary 24-hour standard) and the annual arithmetic mean was 15.9 µg/m^3 (31.8 percent of the primary annual arithmetic mean standard) (DOE, 1994a).

Effluent Air Monitoring

Since 1951, effluent air at Rocky Flats has been monitored. Effluent air monitoring is addressed in detail in Rocky Flats monthly and annual environmental monitoring reports (Dow et al., 1971 to present) and in the Rocky Flats Environmental Impact Statement (EIS) (DOE, 1980). Continuous effluent air samplers are located in the ventilation exhaust systems of each production and research building at Rocky Flats. As is the case with the ambient air monitoring program, the sampling and analytical protocols for effluent air monitoring have varied throughout the history of Rocky Flats. Plutonium analysis of selected effluent air samples began in 1975; before this, airborne effluents were analyzed for total long-lived alpha radiation only. Under current protocol, effluent air samples are analyzed at regular intervals for total long-lived alpha activity. Individual samples from each exhaust system are composited monthly into area-specific samples, which are analyzed for plutonium, americium, uranium, and beryllium. Suspect exhaust streams are also analyzed for tritium concentration three times each week.

In 1993, radionuclide emissions data from effluent air monitoring showed that the projected doses to the public were within the national emission standards for hazardous air pollution limits of 10 millirem per year (mrem/year) effective dose equivalent (DOE, 1994a).

Soil Monitoring

Beginning in 1984, soil samples have been collected annually by Rocky Flats to evaluate changes in plutonium activity in surface soil. The soil monitoring program is addressed in detail in Rocky Flats annual environmental monitoring reports (Dow et al., 1971 to present). Under current protocol, soil samples are collected once per year from 40 sites located on concentric circles 1 and 2 miles (1.6 and 3.2 km) in radius from the center of Rocky Flats and are analyzed for plutonium (Figure 1-5). A similar soil sampling program was conducted in 1977, with the addition of 17 samples collected from locations within a 5-mile (8 km) radius from the center of Rocky Flats.

The results of the 1993 soil samples collected from the inner concentric circle ranged from 0.04 picocuries per gram (pCi/g) to 18.79 pCi/g. The sample locations for the inner circle are all located within the Rocky Flats buffer zone. Samples from the outer concentric circle ranged from no reading to 4.55 pCi/g. The highest plutonium concentrations were found in soil samples collected from the eastern portion of the buffer zone. These sample locations are east and southeast of the 903 Pad area. Figure 1-5

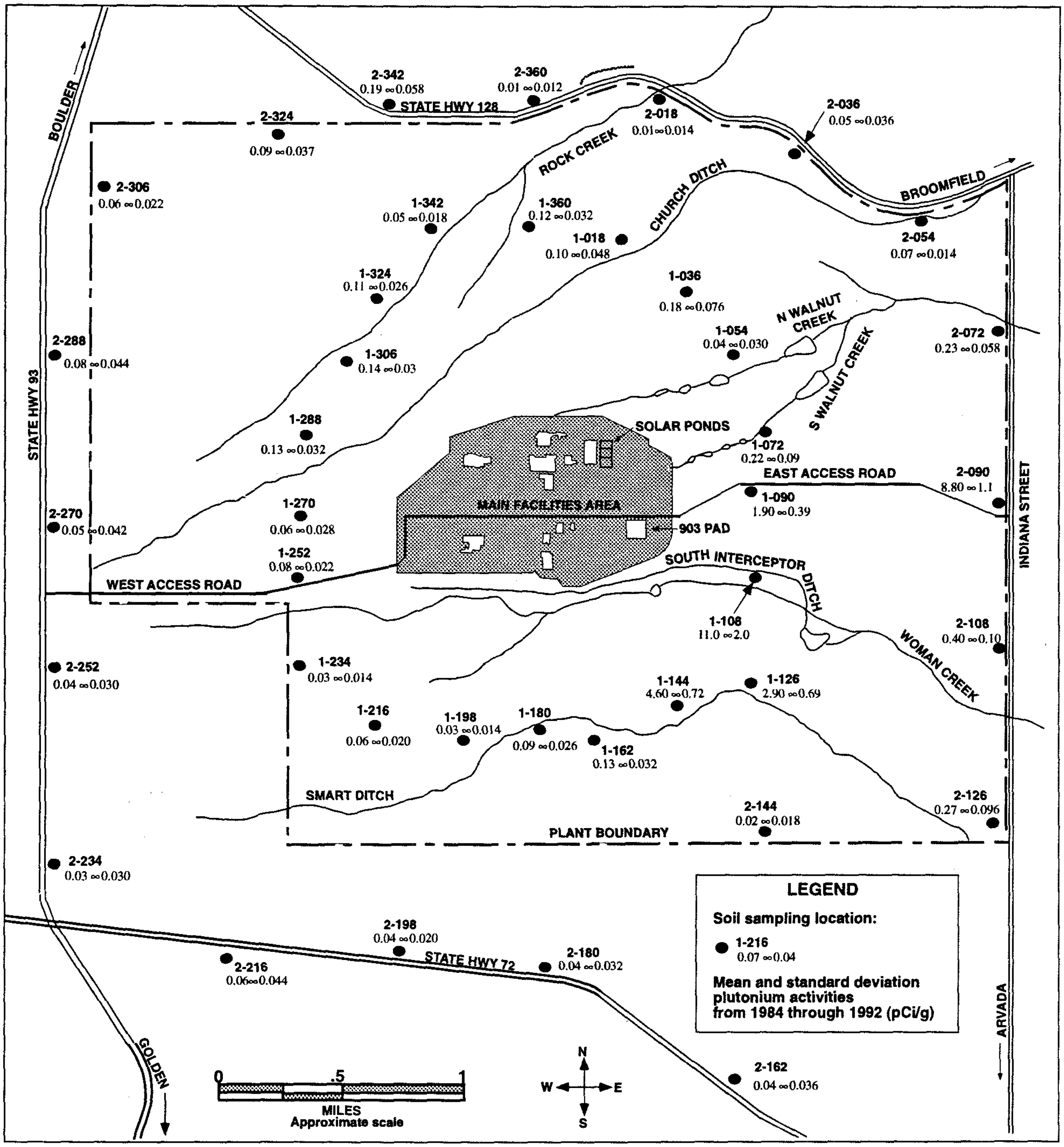

Figure 1-5 Soil Sampling Locations (from EG&G, 1994c).

presents the mean and standard deviation of observed soil plutonium concentrations from 1984 through 1993 in pCi/g (DOE, 1994a).

The CDPHE also monitors plutonium activities in the surface soils of areas near Rocky Flats (CDPHE, 1990a). Under this program, five subsamples are collected within each of 13 predefined sectors and composited into a single sample, which provides an average soil plutonium concentration within the sector. Surface soil samples also are collected from eight Colorado locations remote from Rocky Flats in order to assess plutonium activities concentrations attributed to worldwide atmospheric fallout. The CDPHE soil sampling program was conducted annually between 1970 and 1978, and in 1980, 1981, 1986, and 1989. Results are published in Rocky Flats environmental surveillance reports prepared monthly by the CDPHE (CDPHE, 1970 to present). A summary table of results between 1970 and 1986 is included in CDPHE (1990a). Several of the past sampling programs, including the 1989 program, have included analysis of selected radionuclides other than plutonium, and beryllium (CDPHE, 1990a). The results of the beryllium analyses reported concentrations below method detection limits.

Surface Water Monitoring

Since 1951, routine monitoring has been conducted of surface water within and around Rocky Flats of all effluent streams and local municipal water supplies. Figure 1-6 shows the holding ponds and liquid effluent water courses (treated sanitary waters and surface water runoff) at Rocky Flats. Specific sampling by location and analytical protocols have varied throughout the history of the surface water monitoring program. Information regarding sample locations, analytical protocols, analytical results, and compliance with applicable state and federal water quality standards has been summarized since 1971 in Rocky Flats monthly and annual environmental monitoring reports (Dow et al., 1971 to present). The surface water monitoring program is also summarized in the EIS for Rocky Flats (DOE, 1980).

Water quality in Great Western Reservoir and offsite reaches of Walnut Creek are routinely monitored by Rocky Flats, the City of Broomfield, and the CDPHE. The City of Broomfield samples Walnut Creek at a location immediately east of the eastern site boundary on a monthly basis and tests for eight VOCs. An automatic sampler at the same location collects a composite water (Figure 1-6) sample each week for analysis of gross alpha and gross beta radiation. Weekly samples are also collected by the City of Broomfield from Walnut Creek below Great Western Reservoir and analyzed for gross alpha and gross beta radiation levels. Water entering the Broomfield water treatment plant from the reservoir is monitored monthly for eight VOCs. Treated Broomfield tap water is also monitored weekly for gross alpha and gross beta radiation, and monthly for eight VOCs (CDPHE, 1989). The CDPHE conducts quarterly sampling of Great Western Reservoir water for selected herbicides, pesticides, metals, base-neutral acids (BNAs), and radionuclides. Influent to the Broomfield water treatment plant from Great Western Reservoir is analyzed weekly by the CDPHE for selected radionuclides (CDPHE, 1990b).

The Cities of Northglenn, Thornton, and Westminster each monitor raw water influent from Standley Lake at their respective water treatment plants for VOCs, gross alpha, and gross beta radiation. The City of Westminster also monitors treated tap water for gross alpha and gross beta radiation.

Woman Creek is sampled immediately east of the site boundary once each month by the City of Thornton and analyzed for 59 VOCs. Woman Creek is also sampled weekly for analysis of gross alpha and gross beta. Standley Lake is sampled monthly near the Westminster treatment plant inlet and analyzed for 59 VOCs. The Cities of Thornton, Northglenn, and Westminster eliminated VOCs from their sampling programs because VOCs have not been detected. Water is also sampled monthly near the Standley Lake

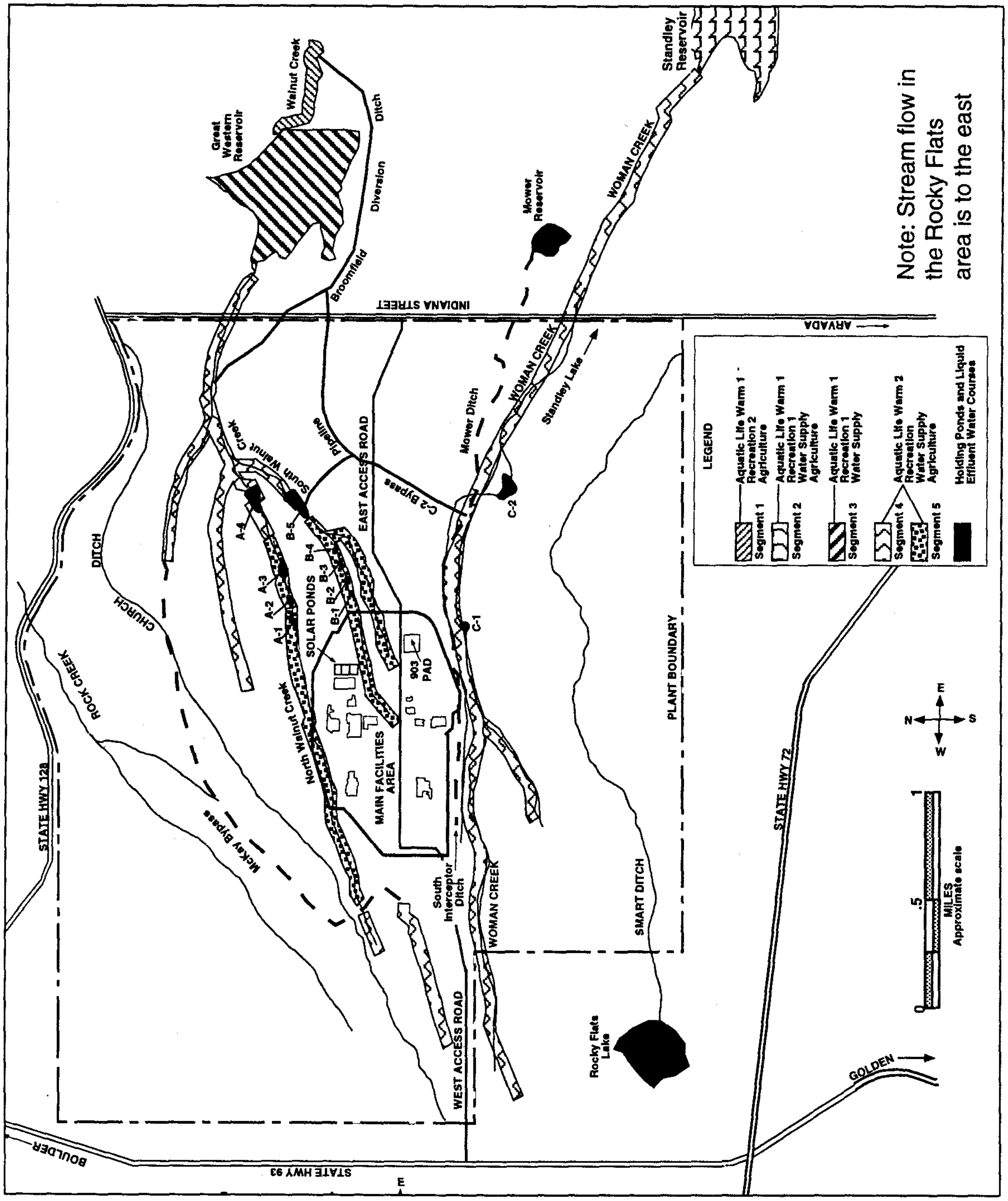

Figure 1-6 Holding Ponds and Liquid Effluent Water Courses (from EG&G, 1994c).

dam at six different depths for gross alpha and gross beta radiation analyses (CDPHE, 1989). The CDPHE conducts quarterly sampling of Standley Lake for analyses of selected herbicides, pesticides, metals, BNAs, and radionuclides. Standley Lake influent to the Westminster water treatment plant is analyzed weekly by the CDPHE for selected radionuclides (CDPHE, 1990b).

Rocky Flats, the CDPHE, and municipal monitoring programs have produced a large volume of data to assess the potential impacts from Rocky Flats releases on surface water. The monitoring is conducted in part to ensure that Rocky Flats meets applicable state and federal water quality standards. Applicable standards have varied since the opening of Rocky Flats in 1951, and currently include:

- **The National Pollution Discharge Elimination System (NPDES) standards** for Rocky Flats, first issued in 1974, which limit nonradioactive discharges from the plant.

- **State of Colorado drinking water standards** for radioactive contaminants in community water systems, promulgated in 1977.

- **Site-specific standards established by the Colorado Water Quality Control Commission (CWQCC)** for both radioactive and nonradioactive constituents. These standards were adopted in July 1989 for the upper segments of Big Dry Creek basin.

Descriptions of these standards, and information about Rocky Flats compliance with the standards, are contained in the Site Monthly and Annual Environmental Monitoring Reports (Dow et al., 1971 to present).

In 1993, Rocky Flats community water monitoring program included sampling and analysis of public water supplies and tap water from several communities surrounding Rocky Flats. Only Great Western Reservoir and Standley Lake have the potential to receive runoff from Rocky Flats drainage systems. All discharges from Rocky Flats detention ponds were diverted to the Broomfield Diversion Ditch and did not enter either Great Western Reservoir or Standley Lake Reservoir. During 1993, weekly samples were collected and composited into a monthly sample, and analyzed for plutonium, uranium, and americium. Tritium and nitrate (as nitrogen) analyses were conducted on weekly grab samples (DOE, 1994a). Annual background samples were also collected from Ralston, Dillon, and Boulder reservoirs, as well as from South Boulder Diversion Canal at distances ranging from 1 to 60 miles from Rocky Flats. Samples were collected to determine background levels for plutonium, uranium, americium, and tritium in water (DOE, 1994a).

Drinking water from Boulder, Broomfield, and Westminster was collected weekly, composited monthly, and analyzed for plutonium, uranium, and americium. Analyses for tritium were performed weekly. Tap water samples were collected quarterly from the communities of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton. These samples were analyzed for plutonium, uranium, americium, and tritium (DOE, 1994a).

Plutonium, uranium, americium, and tritium activities for regional reservoirs represented less than 0.24 percent of the applicable derived concentration guidelines. Average plutonium activity in Great Western Reservoir was 3×10^{-12} μCi/ml (0.11×10^{-4} Bq/l), which is negligible compared to the derived concentration guideline (EG&G, 1994c).

Results of plutonium, uranium, americium, and tritium analyses for drinking water in nine communities were 0.09 percent or less of the applicable derived concentration guideline. During 1993, the highest mean activity of alpha-emitting radionuclides for community tap water was 1.6×10^{-11} µCi/ml (5.92×10^{-4} Bq/l). This value was 0.11 percent of the State of Colorado and EPA drinking water standards for alpha activity. The average tritium concentration in Great Western Reservoir, Standley Lake, and in all community tap water samples was less than 4.6×10^{-8} µCi/ml (1.702 Bq/l). The value is typical of background tritium concentrations in Colorado and is less than 0.23 percent of the State of Colorado and EPA drinking water standards for tritium.

These data are from 1992 sitewide surface water sampling programs. 1993 data were not provided because the sampling program was concluded. The annual sitewide programs have provided 5 years of monitoring data sufficient in quality and quantity to meet DOE Order 5400.1 characterization requirements.

Groundwater Monitoring

A total of 56 groundwater monitoring wells were installed at Rocky Flats between 1960 and 1985. Most of these wells were located within the controlled area of the plant (Figure 1-7) and targeted specific sites of suspected groundwater contamination (DOE, 1994a).

Limited completion data and sampling data are available for these pre-1986 wells. The sampling frequency for these wells varied from quarterly to biannually. Until 1985, samples were analyzed for selected radionuclides only; beginning in 1985, other chemical parameters (VOCs, metals, and inorganics) were added (Rockwell, 1989b).

In 1986 and 1987, 137 monitoring wells were installed as part of the DOE Comprehensive Environmental Assessment and Response Program (CEARP) for Rocky Flats. CEARP later became the Environmental Restoration (ER) Program. These wells were drilled in part to meet RCRA requirements for the four regulated units at OUs at Rocky Flats and also targeted other known IHSSs at Rocky Flats. The 1986 monitoring wells included four wells along the eastern boundary of the site (downgradient of the main production facility) to assess potential contaminant movement offsite through groundwater. Also included were background characterization wells in onsite areas believed to be unaffected by activities from Rocky Flats (Rockwell, 1989b). An additional 150 wells were installed in 1993 to further characterize the hydrogeology of Rocky Flats, including the Woman Creek Drainage (OU 5), Walnut Creek Drainage (OU 6), and present landfill (OU 7) (DOE, 1994a).

By the end of 1993, 676 monitoring wells had been installed, of which 430 were sampled on a regular basis. Groundwater samples are collected quarterly from the alluvial and bedrock wells and analyzed for field parameters, selected radionuclides, metals, organics, inorganics, and anions. Semivolatile and pesticide/polychlorinated biphenyl (PCB) analyses were performed the first quarter after a well was installed. Monthly and/or quarterly water level measurements were taken when the wells were sampled (DOE, 1994a).

More detailed information regarding the Rocky Flats groundwater monitoring program is provided in the Site Annual Environmental Monitoring Reports (Dow et al., 1971 to present). Since 1988, groundwater monitoring results for RCRA-regulated Interim Status Units at Rocky Flats have been provided in annual RCRA groundwater monitoring reports (Rockwell, 1989b; EG&G, 1990b).

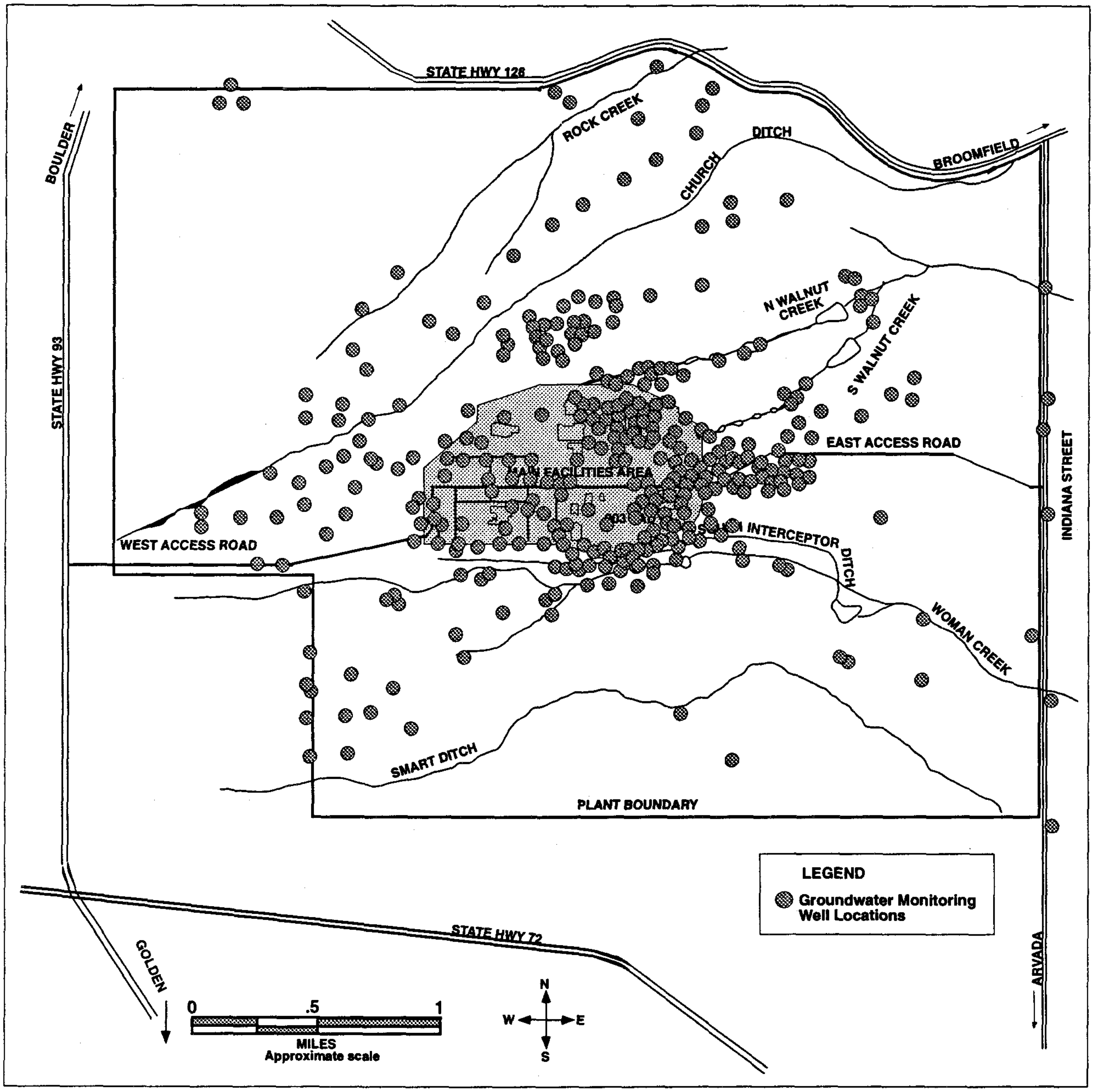

Figure 1-7 Location of Monitoring Wells
Source: EG&G, 1994c

Currently available analyses of the hydrogeologic relationships indicate that there are no known bedrock pathways through which groundwater contamination may directly leave Rocky Flats and migrate into a confined aquifer system outside the site boundary (DOE, 1994a).

1.3.7 Other OU Activities and Relevant Work

Other Operable Units

Sixteen OUs have been identified at Rocky Flats under the Rocky Flats IAG. Under the IAG, the DOE is required to conduct an RI/FS/RFI/Corrective Measures Study (CMS) for the OUs. The OUs that OU 3 may interact with include OUs 2, 4, 5, and 6.

Rocky Flats environmental personnel are currently performing the following OU research:

- OU 2 studies on the 903 Pad, which is believed to be the source area for contamination associated with OU 3.
- OU 4 studies on two solar evaporation ponds.
- OU 5 and 6 studies on onsite reaches of Woman Creek and Walnut Creek, respectively. The drainages from these creeks flow offsite and through OU 3.

Work efforts for OU 3 have been coordinated with OUs 2, 4, 5, and 6. As information from other OUs has become available, the data have been reviewed and incorporated into this document, as appropriate.

Surface Water Management

Other relevant activities affecting OU 3 include the work being done as part of the Option Review Group. In April 1990, Colorado Congressman David Skaggs organized a committee to develop and evaluate surface water management options for the Woman Creek and Walnut Creek watersheds. As a result, the Option Review Group was formed. The Option Review Group developed and evaluated at least eight options for management of surface water flows from Rocky Flats. The group recommended Option B, which would detain and divert Woman Creek flows to protect Standley Lake during a 100-year flood event, and replace Great Western Reservoir as a drinking water supply. Activities for OU 3 have been coordinated with work associated with Option B.

<u>Standley Lake Protection Project</u> - The Standley Lake Protection Project (SLPP), the first major component of the Option B process, is in the final stages of implementation. Comprehensive planning, preliminary design, and permitting activities were completed during 1994, and construction, begun in September 1994, is scheduled for completion by 1996.

To obtain necessary agency approvals and permits, the Standley Lake Cities (Westminster, Northglenn, and Thornton) undertook a series of detailed, project-specific environmental studies, including: an Environmental Assessment regarding general environmental impacts and mitigation measures, a Biological Assessment with respect to Threatened and Endangered Species, Fugitive Dust Modeling, and a HHRA for construction, development of a detailed operations plan/agreement between the Standley Lake Cities and DOE to govern facility operations, and design of replacement wetlands to mitigate for project wetland impacts. The Cities also conducted a public outreach program with numerous public meetings, and coordinated extensively with various federal, state, and local agencies, including the DOE, EPA, Corps of Engineers (COE), Fish and Wildlife Service (FWS), CPDHE, Colorado Division of Wildlife (CDOW), and Jefferson County. These efforts culminated in the September 1994 issuance of necessary construction approvals and permits, including a favorable Biological Opinion from the FWS, a Nationwide 404 Permit from the COE, and a Fugitive Particulate Emission Permit from CDPHE.

The SLPP will use a detention reservoir and other associated surface water management features that will physically isolate Standley Lake, the municipal water supply for approximately 200,000 people from runoff originating on Rocky Flats. The detention reservoir will be built to contain a 100-year storm event. These facilities will divert and temporarily store runoff in Woman Creek so that it can be tested for possible contaminants. If the water does not meet applicable water quality requirements, it will be retained for appropriate action prior to release. After verification that the water meets applicable water quality requirements, the water will be pumped over to Walnut Creek for downstream beneficial use. Key project components, and their current status, are summarized below:

1. Woman Creek Reservoir—an 850 acre-foot, off-channel reservoir to store Woman Creek stream flows for testing, and treatment if necessary, prior to release, up to the 100-year storm event. Construction began in April 1995 after nesting Bald Eagles left the Standley Lake area, and is expected to be completed by early Fall 1995, prior to the eagles' return. If construction cannot be completed by this time, the work will resume in April 1996 after the eagles' departure, and be completed by Summer 1996. The reservoir is engineered for a 100-year storm event.

2. Woman Creek Reservoir Pump Station and Pipeline—to convey water released from Woman Creek Reservoir to Walnut Creek, located just downstream from Great Western Reservoir. Construction bids were received in April 1995, and construction is scheduled for Summer 1995 prior to the bald eagles' return to Standley Lake.

3. Kinnear Ditch Pipeline—to convey Westminster water rights in a protected environment extending from the mouth of Coal Creek to Standley Lake on the south side of Rocky Flats (formerly conveyed through Rocky Flats via Woman Creek). Construction of the pipeline began in September 1994 and was completed in March 1995.

4. Wetlands Mitigation Site and Wildlife Habitat Acreage—11 acres of new wetlands are being built just west of Standley Lake to mitigate wetlands disturbed by construction of other SLPP components. Construction began in September 1994, and planting began in April 1994, after departure of the Bald Eagles at Standley Lake. This site, and 375 additional acres purchased from Jefferson County (located just north of Woman Creek Reservoir), are being dedicated as habitat for Bald Eagles and other area wildlife.

In addition to the infrastructure components of the project, the SLPP will incorporate provisions for long-term operations and maintenance. These provisions are described in a nearly completed Operations Agreement between the Standley Lake Cities and the DOE. The plan describes responsibilities and protocols for testing and treatment under routine streamflow and storm event conditions, as well as for potential spill events. It also sets aside an Operations and Maintenance escrow fund for normal operations and maintenance activities, as well as an Emergency Response escrow fund for timely cleanup/treatment in response to an unforeseen spill event.

Great Western Reservoir Project - The present status (August 1995) of the various components of the Great Western Reservoir Project is as follows.

The City of Broomfield completed its purchase of "Windy Gap" water rights in 1993. This purchase of 4,300 acre-feet from the City of Boulder, combined with the City's other Windy Gap water rights holdings, provides the City with 5,600 acre-feet of Windy Gap water, deliverable in Carter Lake. The City of Broomfield has not expended funds for the firming of the 4,300 acre-feet of Windy Gap water purchased from Boulder. Study of options for firming are underway.

The raw-water pipeline to convey Broomfield's water from Carter Lake to Broomfield is being constructed by the Northern Colorado Water Conservancy District. By contracting with the District for design, construction, and operation of the pipeline, Broomfield made it possible for other Colorado entities to participate in the pipeline project, with each participant paying their pro-rata share of pipeline costs. This arrangement, with its resulting economics of scale, not only reduced the project cost for Broomfield, but also made it economically viable for other entities to utilize their Carter Lake water to improve the quality and dependability of their water supplies. The raw-water pipeline is expected to reach Broomfield in the Summer of 1995, with a delivery capacity of 12.4 cfs.

Broomfield has completed construction of its terminal storage reservoir, located at the terminus of the raw-water pipeline, near West 144th Avenue and Lowell Boulevard. This 300 acre-feet capacity reservoir provides emergency storage adjacent to the City's new water treatment facility, and provides flow equalization capability to accommodate small differences in delivery rate from the raw-water pipeline and treatment rate of the water treatment facility. The terminal storage reservoir was designed by Rocky Mountain Consultants, Inc., and constructed by R. E. Monks Construction Co.

Rocky Mountain Consultants, Inc. is completing final design of the water treatment facility, with construction of the facility planned to be underway by mid-summer 1995. The facility will have a nominal design capacity of 8 mgd. The facility is expected to be on-line in late 1996.

The treated-water pipeline to connect the new water treatment facility with Broomfield's existing potable water distribution and storage system is being designed in two phases. Preliminary design of the first phase, from the new water treatment facility to the existing Carbon Road storage tank is presently underway. Feasibility design and route selection is underway for Phase II, which involves a booster pumping station near the Carbon Road storage tank, and a new pipeline to storage in the vicinity of the Jefferson County Airport. Construction of the pipeline system for treated water is expected to take place in 1995.

The City of Broomfield has completed sale of its Marshall water rights, and is presently negotiating sale of its Great Western Reservoir related water rights in order to generate project income as agreed to in the grant.

Rocky Flats Nuclear Weapons Plant Dose Reconstruction Project

Health studies on Rocky Flats are being conducted by ChemRisk under contract to the CDPHE. Phase I is known as the Rocky Flats Toxicologic Review and Dose Reconstruction Project. Phase II studies are currently analyzing the Toxicity Assessment and Risk Characterization of Rocky Flats.

The primary purpose of Phase I is to reconstruct potential doses of the COCs that may have been received by offsite individuals as a result of past Rocky Flats operations. The project was not designed to estimate doses from present and future operations or anticipate future exposure potentials. This project is also evaluating doses to individuals offsite, as opposed to occupational exposures to site workers.

The eight technical tasks associated with the Phase I Health Studies are as follows:

1. Identify Chemicals and Radionuclides Used
2. Select Chemicals of Concern
3. Reconstruct History of Operations
4. Identify Release Points
5. Estimate Releases
6. Select and Model Exposure Pathways
7. Characterize Land Uses and Demographics
8. Perform Dose Assessment

Although the endpoint of the Phase I studies is dose estimates, Phase II investigates dominant sources of past exposure, consequent health risks, and possible changes in estimated doses or refinements in uncertainty estimates.

Citizens' Environmental Sampling Committee

The Citizens' Environmental Sampling Committee (CESC) was created by the Health Advisory Panel Sampling Subcommittee (HAP) in December 1992 to augment the sampling programs of the HAP Rocky Flats Health Studies. The CESC consists of local citizens and environmental interest group members. In 1993, the CESC began developing a soil and sediment sampling program with consultation and assistance from the CDPHE, the Colorado State University (CSU) Radiological Health Sciences Department, and other analytical and technical professionals. With support from these groups, the soil investigation was directed, implemented, and reported by the CESC members. The CESC study is unique among all previous soil and sediment investigations associated with Rocky Flats because it was directed from beginning to end by local citizens.

The CESC soil sampling report has not been published to date. Results of the CESC soil investigation are expected to be available prior to the submittal of the Final RFI/RI report. If so, these results will be included in the Final RFI/RI report for comparison to results of the OU 3 soil investigation.

Joint Soil Sampling Program

As part of the CESC study, a joint surficial soil sampling program was initiated at three OU 3 sampling sites. This sampling allowed participants, (DOE, CDPHE, and CSU) to supplement their respective studies and provide some level of comparability between sampling techniques and laboratories. In the sampling program, each sample was split three ways and analyzed separately by a DOE-designated laboratory, the CSU radiological laboratory, and by a laboratory selected by the CESC. Potential sampling locations were identified that would yield enough material to supply 10 to 12 soil samples so that each party would be provided adequate sample material for proper analysis. The joint sampling program also provided the opportunity for CESC members to observe first-hand, the techniques utilized for sample collection by the DOE and its contractors.

Results of the joint soil sampling program are not yet published, but will be made available upon publication of the CESC report.

PCB Sediment and Tissue Sampling

A sediment and tissue (PCBs) sampling project was initiated because of the potential for sediments and/or specific biota in Great Western Reservoir to have been impacted by PCB contaminants from Rocky Flats. Prior to 1989, Walnut Creek discharged into Great Western Reservoir and back into Walnut Creek below the dam.

As shown in Appendix L, results from the sediment sampling (June to July 1994) revealed no detectable level of PCBs in terminal ponds located upstream of Great Western Reservoir. This finding indicates that it is unlikely that sediments derived from Rocky Flats contributed PCBs to any offsite reservoirs or downstream ecosystems. The decreasing trend in PCB concentrations in fish tissue samples from the upstream PCB source (onsite) to downstream ecosystems supports this finding. Elevated PCB concentrations detected in fish tissue samples collected from Standley Lake are not likely associated with Rocky Flats sources because historically, Rocky Flats has contributed less than 5 percent of the surface water inputs to this reservoir and upstream areas closer to Rocky Flats have lower or nondetectable PCB concentrations. In addition, because no PCBs were detected in any samples of the small mammal tissue collected from around the terminal ponds, it is evident that PCBs have not bioaccumulated in terrestrial food chains.

2.0 OU 3 FIELD INVESTIGATIONS

Field investigations were performed at OU 3 to meet the RFI/RI objectives specified in the EPA and CDPHE-approved OU 3 Work Plan (DOE, 1992a.) Based on the RFI/RI objectives, OU 3 specific data quality objectives (DQOs) and data needs were identified in Table 5-1 of the OU 3 RFI/RI Work Plan. Soil, surface water, sediment, groundwater, air quality, meteorological, and ecological data collection comprised the field work to help achieve the DQOs. Table 2-1 summarizes the field activities including the objectives, the activity proposed in the OU 3 Work Plan, analyses performed during field investigations, refinements to the work plan, and summary of the work completed.

2.1 OVERVIEW OF FIELD INVESTIGATIONS

The field investigations were performed in accordance with the EPA-approved RFI/RI Final Work Plan for OU 3 (DOE, 1992a), Technical Memorandum (TM) No. 1 Addendum to the Final RFI/RI Work Plan for OU 3 (DOE, 1993b), and relevant Standard Operating Procedures (SOPs) (DOE, 1991a). Refinements of these documents are described in the following subsections. The investigations for each medium are described including the sampling program objectives, summary of data collection activities, analyses requested, and refinements to the work plan. A general summary of the sample type, number of sample locations, number of samples, and analyses requested by medium is presented in Table 2-2. Specific sample tracking information is included in Appendix C.

2.2 SOIL INVESTIGATIONS

The OU 3 soil investigation focused on sampling surface and subsurface soils to characterize vertical and lateral extent of plutonium, americium, and uranium contamination. Because of the prevailing wind conditions and results from previous soil investigations, the OU 3 areas with the highest plutonium activities are believed to be located east of the site buffer zone boundary. The soil investigation focused primarily on the area east of Indiana Street (Figure 2-1).

2.2.1 Surface Soil Investigation

The surface soil investigation consisted of sampling plots within the OU 3 study area boundaries. Sampling plots were located north, east, and south of the site boundary. Because of the inability to gain access to some private lands within OU 3, samples from certain locations specified in the OU 3 Work Plan were not collected, however, substitute sites were selected in order to sample the required number of locations. As a result, a total of 61 surface soil locations were sampled, one more location than specified in the OU 3 RFI/RI Work Plan. Changes to the work plan were presented in TM No. 1 (DOE, 1993b).

Objectives

The objectives of the surface soil sampling were to delineate the lateral extent of plutonium, americium, and uranium contamination and to compare results obtained from previous soil investigations in OU 3. The surface soil plots (10-acre square plots) were located in a grid that extended approximately 3 miles east of Indiana Street and over 4 miles north to south. The plots were located approximately 1,000 meters apart, providing extensive coverage of the surface soils within OU 3. Some of the sample locations were collocated with terrestrial samples. Figure 2-1 presents the locations of the 10-acre soil plots.

Table 2-1
Summary of OU 3 Field Investigations

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
1. Characterize lateral extent of soil contamination.	Collect surface soil samples using the CDPHE method and analyze samples for plutonium, americium, and uranium. A sampling grid based on geostatistics was used.	Radionuclides (Plutonium-239, -240, Americium-241, Uranium-233, -234, Uranium-235, Uranium-238)	The Rocky Flats method and the CDPHE method were used to collect surface soil samples as described in TM No. 1. The Rocky Flats method was added to enable comparison of OU 3 data to historical data. Both the CDPHE and Rocky Flats methods have been used in the past. TOC, specific gravity, and grain size analyses were not performed on the surface soils. These analyses were performed on the soil trenches. One additional soil plot was sampled over the number specified in the OU 3 Work Plan because of access agreement problems. An additional location was needed to get sufficient a real distribution.	Sixty-one surface soil plots were sampled between June 1992 and June 1993.
2. Characterize vertical extent of soil contamination.	Collect undisturbed soil samples from vertical profile to a depth of approximately 100 cm and analyze for plutonium, americium, and uranium.	Radionuclides (Plutonium-239, Americium-241, Uranium-233,-234, 235, Uranium-238) TOC General soil parameters	None	Samples were collected from vertical soil profiles at eleven locations as specified in the Work Plan. At each trench, samples were collected from 0-3, 3-6, 6-9, 9-12, 18, 24, 36, 48, 72, and 96 cm. Samples were also collected at each soil horizon.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
3. Characterize potential plutonium, americium, uranium, Target Compound List, (TCL) volatiles (Mower Reservoir only), and Target Analyte List (TAL) metals in surface water reservoirs and surface water drainages/ditches.	Collect two rounds of water samples from five locations in Great Western Reservoir, Mower Reservoir, and Standley Lake and analyze for plutonium, americium, uranium, TAL metals, gross alpha, gross beta, atrazine, simazine, cations, and anions. Mower Reservoir will be analyzed for TCL volatiles. Drainage/ditch surface water samples are collected from existing monitoring stations along Indiana Street (SW001, SW002, and SW003). Additional surface water samples will be collected from Broomfield Diversion Ditch, Woman Creek, Smart Ditch, Walnut Creek, Big Dry Creek, Church Ditch (2), and Clear Creek Irrigation Ditch.	**Field Parameters-** Dissolved oxygen, hardness, pH, temperature, alkalinity, turbidity, and specific conductivity **Laboratory Analyses-** Cation/anions TAL metals (dissolved and total) TCL volatiles (Mower Reservoir only) Radionuclides (dissolved and total) Herbicides (atrazine and simazine) Oil and grease Orthophosphate Cyanide Tritium (Great Western Reservoir only)	As described in TM No. 1, fewer surface water samples from the drainages/ditches were collected due to intermittent flow conditions; surface water samples were also analyzed for oil and grease, and hydrogen sulfide to be consistent with analyses from other OUs and to be consistent with SOPs for surface water sampling. Reservoir surface water sampling occurred in July, September, and October, rather than during high and low reservoir capacity.	A total of 53 surface water samples were collected from 33 locations. Surface water samples were collected from Standley Lake, Great Western Reservoir, and Mower Reservoir in July, September, and October 1992. Samples collected in July and October were collocated with sediment and biota sampling. Surface water samples collected in September were collocated with sediment core samples. Additional reservoir surface water samples were collected and collocated with biota samples to obtain representative samples. Six drainage locations were sampled during the surface water investigation: Walnut Creek, Dry Creek Valley Ditch, Woman Creek, Broomfield Ditch, Big Dry Creek, and Coal Creek.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
4. Characterize the potential horizontal extent or surficial plutonium, americium, uranium, TCL volatiles, and TAL metals contamination in drainages/ditches and reservoir sediments.	A total of 29 sediment sampling locations will be sampled from drainage/ditch locations at Walnut Creek, Broomfield Diversion Ditch, Woman Creek, Church Ditch, stations along Indiana Street, Clear Creek Irrigation Ditch, Smart Ditch, and Big Dry Creek. A total of 38 sediment sampling locations will be sampled from Mower Reservoir (5), Great Western Reservoir (15), and Standley Lake (18). All sediments are to be analyzed for plutonium, americium, uranium, gross alpha/beta, TAL metals, and cyanide. Mower Reservoir sediments are to be analyzed for TCL volatiles. Great Western Reservoir sediments are to be analyzed for tritium.	Radionuclides TAL metals TCL volatiles (Mower Reservoir only) Tritium (Great Western Reservoir only) Cyanide TOC Specific gravity Grain size	Eight sediment samples were collected along drainages associated with the Walnut Creek drainage area. Ten were proposed in the Work Plan. Along Woman Creek, 11 locations were sampled. At Mower, five locations were sampled along Mower Ditch, and four nearshore locations were sampled. Sediment sample locations were not those specified in the Work Plan because field conditions varied. Drainage samples were collected at Coal Creek, Smart Ditch, Walnut Creek, Church Ditch, Big Dry Creek, Woman Creek, and Broomfield Diversion Ditch.	A total of 24 drainage/ditch sediment locations were sampled during the OU 3 field investigation. In addition, 46 reservoir locations were sampled. Several sediment locations were sampled twice, once in July and once in October.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
5. Characterize potential vertical extent of radionuclide and metal contamination in reservoir sediments.	Sample a total of 10 vertical profile reservoir sediment locations using a gravity coring device at the three reservoirs and analyze them for plutonium, americium, and uranium. Three cores will be taken at Great Western Reservoir and Mower Reservoir, and four at Standley Lake.	Radionuclides Gross alpha/beta Cesium-137 Polonium-210 TAL metals Cyanide	Cesium-137, Polonium-210, TAL metals, and cyanide were added to the list of analyses for the vertical core samples. The Cesium-137 and Polonium-210 analyses were added to help age-date the core. Metals and cyanide were added to evaluate redox conditions at the sediment/water interface, assess mobility of metals, evaluate movement of metals from sediment to the water column and compare results to previous studies. Because of the shallow depth of water at Mower Reservoir, the coring device was manually driven. Recovery of a full 30 inches of core was not possible at every location because of substrate conditions. Additional cores were collected from Standley Lake and Great Western Reservoir to provide more information for the evaluation of nature and extent of contamination. Also, the two additional vertical core samples collected from Great Western Reservoir will allow evaluation of detections of plutonium by the City of Broomfield that occurred after the Work Plan was approved.	A total of 12 vertical core samples were collected: 4 from Standley Lake, 5 from Great Western Reservoir, and 3 from Mower Reservoir.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
6. Characterize potential plutonium, americium, and uranium entrapment of sediments exposed along the reservoir shoreline and near-shore sediments.	Collect sediments samples along the reservoir shorelines of Great Western Reservoir (15), Mower Reservoir (15), and Standley Lake (5). In addition, one vertical profile sample was proposed at each reservoir.	Radionuclides Gross alpha/beta TAL metals Cyanide TCL volatiles (Mower Reservoir only) TOC, specific density, and grain size	Four near-shore sediment locations were sampled along Mower Reservoir instead of five. Four vertical profile samples were collected at Standley Lake and three at Great Western Reservoir to a depth of 6 inches instead of one. The additional core samples collected closer to the water line at Standley Lake and Great Western Reservoir were collected to allow for the comparison on how radiological concentrations at the sediment surface vary through the reservoir (whether exposed or unexposed).	Thirty-four near-shore sediment locations were sampled. At eight of the locations, a vertical profile sample was also collected from 0-1 inch, 1-2 inches, 2-3 inches, 3-4 inches, 4-5 inches, and 5-6 inches.
7. Characterize potential contamination in the groundwater from sediment/groundwater interactions and surface water/groundwater interactions if present.	Collect groundwater samples from groundwater monitoring wells located downgradient of both Great Western Reservoir and Standley Lake.	Radionuclides Cations/anions Nitrates TAL metals	Although they were not specified in the OU 3 Work Plan, metals were analyzed in the groundwater samples. The metal analyses were included to be consistent with analyses from the comprehensive RFP environmental monitoring. Wells were sampled monthly for approximately 1 year rather than quarterly.	Two groundwater monitoring wells were drilled and sampled monthly for metals and radionuclides. In addition, water levels were also collected monthly.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
8. Characterize particulate in air.	Collect discrete air samples from exposed reservoir sediments and vegetated soil area using a wind tunnel and analyze air samples for plutonium, americium, and uranium. Two continuous air samplers will also be installed near Standley Lake. Existing Rocky Flats Radionuclide Ambient Air Monitoring Program (RAAMP) samplers located in the community will be used for background data evaluations.	Radionuclides	Screening tests using the wind tunnel were only performed at three of the six shoreline locations because, during the second sampling event, the proposed locations were covered with water. At S-4, three screening tests were performed instead of the specified two because of field conditions. The shoreline location had a large area of silt deposited on top of the rocky sediment.	Wind tunnel studies are complete.
9. Characterize vegetation types.	Conduct field reconnaissance for species and cover using quadrant sampling.	Field surveys	Vegetation cover plots followed the revised SOPs and were located along point-intercept and belt transects of 50 meters; production plots were clipped separately (SOP) and were changed to be collocated and sampled on soil trenches; an additional page was added to the habitat description form, and additional environmental scalers added for habitat determination. Late season sampling was not conducted due to the biotic variables not changing, so a second sampling of the vegetation and mammals populations was no longer applicable.	Nine sites (four to eight transects each) of belt transects and point intercept; 13 sites (five plots each) of releve and production plots plus three additional production plots.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
10. Characterize animal species and populations.	Conduct field surveys for major species of mammals, birds, and reptiles.	Field surveys	Small mammal trapping grids were reduced to a small grid of 25 traps as allowed in the SOP; small mammal trapping procedures changed were (1) measuring total body and tail length, (2) marking captured animals, and (3) completing trap check within 4 hours of sunrise (captured animals were marked with hair clip rather than a pelage dye; and on some traps, line checking was completed up to 11 a.m.).	13 small mammal grid trappings; 10 quantitative and 8 qualitative bird surveys; 12 qualitative herpetologic surveys.
11. Characterize wetlands/riparian zones.	Conduct qualitative survey for types, size, location, and major species.	Field surveys	None	Five qualitative surveys were conducted.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
12. Assess bioaccumulation in vegetation.	Analyzes tissue samples from above-ground plant biomass for plutonium, americium, and uranium.	Radionuclides	Added three vegetation sampling locations to increase sample numbers for analysis based on review of early data from OU 1 and OU 2 as stated in TM No. 1. The quantitative vegetation and small mammal pots were located directly over the proposed soil trenches or site soil plots. Plots were used concurrently for vegetation productivity (clipped and estimated), cover (estimated to nearest percent), plant tissue samples, and for small mammal trapping grid and animal tissue collection. Clipped plant material was composited rather than separated by species. Clipped plant material was not oven-dried, but frozen immediately and stored until shipped to laboratory. Some of these sites were sampled both for the more standard point-intercept/belt transects conducted for site characterizations as well as collocated quantitative production/tissue measurements. The biotic variables were sampled before the soil trenches because the trenches would have destroyed the vegetation, and soil measurements are not seasonally sensitive.	65 samples were collected at 11 sites.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
13. Assess bioaccumulation and concentration in wetland vegetation.	Analyze tissue samples for plutonium, americium, uranium, and TAL metals.	TAL metals, Radionuclides	As stated in TM No. 1, wetland vegetation was not sampled because of disturbance, heterogeneity, water management, and irrigation currently impacting wetlands.	None
14. Assess bioaccumulation in small mammals.	Analyze tissue samples for plutonium, americium, and uranium.	Radionuclides	Added three additional small mammal trapping grids to increase sample numbers for analysis based on review of early data from OU 1 and OU 2 as stated in TM No. 1. The small mammal plots were located directly over the proposed soil trenches or site soil plots. Plots were used concurrently for vegetation productivity (clipped and estimated), cover (estimated to nearest percent), plant tissue samples, and for small mammal trapping grid and animal tissue collection. Configuration of vegetation plots and small mammal trapping grids were tightened to correspond as close as possible to the soil sample location.	41 samples were collected at 11 sites.

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
15. Characterize benthic macroinvertebrate communities in creeks and reservoirs.	Collect quantitative, semi-quantitative, and qualitative samples. Identify dominant taxa and enumerate. Identify trophic types and spatial distribution.	Species identification Enumeration	OU 3 creek locations were intended to be sampled during both seasonal sampling events. Inadequate flow prohibited sampling at these locations during the late summer field effort.	Benthic macroinvertebrate sampling was conducted in Woman Creek, Walnut Creek, Big Dry Creek, Great Western Reservoir, Mower Reservoir, and Standley Lake. Samples were collected at one station per creek and three to four locations per reservoir.
16. Measure ecological endpoints in benthic macroinvertebrate communities and assess bioaccumulation.	Collect replicate grab samples and dip net or kick net samples. Analyze ecological endpoints. By measuring bioaccumulation in tissue.	None	Bioaccumulation in tissue was not performed. Adequate tissue mass could not be obtained to meet analytical requirements.	Benthic macroinvertebrate sampling was conducted in Woman Creek, Walnut Creek, Big Dry Creek, Great Western Reservoir, Mower Reservoir, and Standley Lake, using Ponar grab sampling techniques in the lakes and a surber sampler within the creeks.
17. Characterize periphyton in creeks.	Collect qualitative samples from natural substrates within creeks.	Relative abundance of major taxa	Work was not performed because inadequate flow prohibited periphyton sampling in creeks.	

Table 2-1a (continued)

Objective	Proposed Activity in OU 3 Work Plan	Analyses Requested During Field Investigation	Refinements to Work Plan	Completed Work
18. Characterize periphyton communities and determine colonization rates in reservoirs.	Collect periphyton on artificial substrates in reservoirs. Identify major types and determine relative abundance. Measure biomass.	Biomass Algae density Taxonomic identification	None	Quantitative periphyton sampling was conducted in Fall 1992 at Great Western Reservoir, Mower Reservoir, and Standley Lake using floating artificial substrate samplers.
19. Characterize fish communities in creeks and reservoirs.	Collect fish with seines, nets, and electroshocking techniques. Identify, enumerate, and measure common species. Determine relative abundance and trophic types.	Species identification Species enumeration Observation of incidence of disease	Fish were not collected for tissue analysis during sampling efforts in Fall 1992 because of low flows.	Fish sampling was conducted in Woman Creek, Walnut Creek, and Big Dry Creek in the Spring of 1992 using electroshocking techniques, and fish were collected from Great Western Reservoir, Mower Reservoir, and Standley Lake using gill nets and boat electroshocking techniques.
20. Measure ecological endpoints in fish communities and assess bioaccumulation and toxicity of contaminants.	Collect fish with seines, nets, and electroshocking techniques. Identify, count, measure, and weigh. Analyze ecological endpoints of bioaccumulation of potential COCs in tissue. Test water/sediments for toxicity.	Species identification Enumeration Tissue analysis for radionuclides and metals	Fish were not collected from streams during sampling efforts in Fall 1992 because of low flows.	Fish sampling was conducted in Woman Creek, Walnut Creek, and Big Dry Creek in Spring 1992 using electroshocking techniques and fish were collected from Great Western Reservoir, Mower Reservoir, and Standley Lake using gill nets and boat electroshocking techniques. Samples of tissue collected from fish from reservoir and lakes were analyzed for radionuclides and metals.

Table 2-2
Number of Locations, Number of Samples, and Analyses Performed for Media in OU 3

Sample Type	No. of Locations	No. of Samples	Analyses Performed
SOILS			
Surface Soils	61	144	Rads
Trench	11	190	Rads
SURFACE WATER			
Creek	6	17	Rads (T,D) Metals (T,D) Water-quality
Lake	27	59	Rads (T,D) Metals (T,D) Water-quality
SEDIMENT			
Creek (Grab)	24	53	Metals Rads VOCs (Mower only)
Lake (Grab)	45	78	Metals Rads VOCs (Mower only)
Lake (Core)	12	118	Rads
Lake (Grab, nearshore)	34	30	Metals Rads VOCs (Mower only)
Lake (Core, nearshore)	8	66	Rads Metals
BIOTA			
Creek	3	9	Species composition
Lake	20	146	Metals Species composition
Mammal/Vegetation	13	107	Rads (T)
GROUNDWATER	2	8	Metals (T,D) Rads Water-quality

LEGEND

Rads = Plutonium-239, -240, Americium-241, Uranium-233, -234, Uranium-235, Uranium-238
T = Total Analyses
D = Dissolved Analyses
VOCs = Volatile Organic Compounds

Summary of Data Collection Activities

Following a lengthy process to obtain permission from private land owners to sample on their land, surface soil samples were collected from the OU 3 study area from June 1992 through June 1993.

The 10-acre plots were sampled by two methods, the CDPHE method and the Rocky Flats method. The CDPHE method (sample numbers were assigned even numbers [e.g., SS04034CH]) consisted of compositing 25 subsamples evenly distributed within each 10-acre plot. This method allowed for the top 1/4-inch of soil to be sampled. The top 1/4-inch of soil is most representative in this sampling event because it can be easily dispersed by wind and has the highest potential for inhalation, direct contact, and ingestion by people. The subsample points were located by pacing combined with the use of a Brunton compass. The Rocky Flats method (sample numbers were assigned odd numbers, [e.g., SS04035CH]) consisted of compositing 10 samples collected from two 1-meter square plots spaced 1 meter apart within each 10-acre plot. Each subsample was collected with a special sampler that collected a volume of 5 cm3 at a depth of 5 cm.

The reference point for any given plot is the southwest corner. For irregularly shaped plots, attempts were made to evenly distribute the sample locations within the plot. The combined subsamples were placed directly into a 500-ml amber glass bottle. Samples were properly labeled and sealed for custody purposes in the field. In addition, chain-of-custody forms were completed at the time of sampling. Samples were then stored in a cooler and transported to the sample management trailer to be inventoried, packaged, and prepared for shipping.

A summary of the samples collected and the quality control samples taken from each sample plot are presented in Appendix C.

Personnel performing surface-soil sampling followed the DOE SOPs for the collection of surface soils.

Analyses Performed

The soil plot samples were analyzed for the following radionuclides: plutonium-239, -240, americium-241, uranium-233, -234, uranium-235, and uranium-238.

Refinements to the Work Plan

The OU 3 Work Plan specified that 10 percent of the soil plot samples be analyzed for total organic carbon (TOC), grain size, and bulk density. None of the soil plot samples were analyzed for these parameters. However, general soil parameters, clay minerals, specific surface area, and bulk density were analyzed in the soil trenches at each distinct soil horizon and these samples provided comparable information for surface soil. An additional plot was sampled because of land access problems and to provide sufficient areal distribution. There were no other refinements to the OU 3 Work Plan.

2.2.2 Subsurface Soil Investigations (Trenches)

The subsurface-soil investigations consisted of sampling undisturbed soil from a vertical profile to a depth of approximately 100 cm. Eleven trenches were excavated for Vertical Profile Sampling and locations east of Indiana Street. The trench sampling locations were selected by reviewing aerial photographs and conducting a site reconnaissance to identify undisturbed areas — the areas where the highest potential for accumulation of contaminants lay.

Objectives

The objective of the subsurface soil investigations was to characterize the vertical extent of the radionuclide contamination (plutonium, americium, and uranium) in OU 3 soils. The trenches were collocated with terrestrial biota sampling locations as shown in Figure 2-1.

Summary of Data Collection Activities for Trench Samples

Subsurface-soil samples were collected by digging a trench 4 x 9 x 4.5 feet deep. The block/staircase method for one wall of the trench was eliminated as described in TM No. 1. Precautions were taken more than once to prevent scraping the trench walls and promoting cross contamination of the soils with depth. Each sample location was clearly marked by placing 12-inch nails at the measured depths, and samples were composited horizontally at the marked sample depth. Samples were collected from each trench in the following intervals: 0 to 3 cm, 3 to 6 cm, 6 to 9 cm, 9 to 12 cm, 18 cm, 24 cm, 36 cm, 48 cm, 72 cm, and 96 cm.

An additional sampling procedure was also conducted for each trench to collect samples for general soil parameters. This procedure involved collecting a set of grab samples at distinct soil horizons encountered in the soil profile trench and then compositing the samples into one sample for each horizon. The resulting sample was collected and placed in a sample container (1-gallon metal can). For custody purposes, samples were properly labeled and sealed in the field. In addition, chain-of-custody forms were completed at the time of sampling. Samples were then stored in coolers and transported at the end of the day to the sample management trailer to be inventoried, packaged, and prepared for shipping.

A summary of the samples collected and of the quality control samples from each soil trench is presented in Appendix C.

Analyses Performed for Subsurface-Soil Samples

The subsurface soil trench samples were analyzed for plutonium-239, -240, americium-241, uranium-233, -234, uranium-235, and uranium-238. The composite sample collected from each distinct soil horizon from each trench was analyzed for general soil parameters, clay minerals, specific surface area, and bulk density.

Refinements to the Work Plan

No refinements to the OU 3 Work Plan and TM No. 1 occurred during the subsurface-soil sampling.

2.3 SURFACE WATER AND SEDIMENT INVESTIGATIONS

The following subsections describe the surface water and sediment field investigations performed for OU 3. The investigations were conducted in conjunction with the biotic sample collection.

2.3.1 Surface Water (Drainages and Reservoirs)

The surface water investigation consisted of sampling the drainages and reservoirs in OU 3. The drainages that were sampled for surface water include Walnut Creek, Woman Creek, Dry Creek Valley Ditch, Church Ditch, Coal Creek, and Big Dry Creek. The reservoirs that were sampled include Standley Lake, Great Western Reservoir, and Mower Reservoir. A total of 53 surface-water samples (excluding quality control samples) were collected from 33 sample locations. Figure 2-2 presents the surface water sampling locations for IHSSs 200, 201, and 202, respectively.

Objectives

The purpose of the OU 3 surface water sampling effort was to characterize radionuclides and metals present within the drainages and reservoirs in OU 3. One objective of the surface water sampling was to evaluate seasonal waterflow fluctuations in the drainages, however, insufficient flows in the drainages at the time of sampling prevented the acquisition of these data.

The specific objectives of the surface-water sampling effort included:

- Characterizing radionuclides, metals, and other inorganic constituents in drainages and reservoirs in OU 3
- Characterizing vertical stratification of radionuclides, metals, and other inorganic constituents in the reservoirs
- Correlating results of surface water sampling efforts between abiotic and biotic samples
- Characterizing temporal distribution of radionuclides and metal concentrations
- Identifying spatial variation of radionuclides, metals, and water quality throughout each of the three reservoirs
- Obtaining necessary data for the human health and ecological risk assessments.

Reservoir samples were collected to characterize the vertical stratification of radionuclides and metals. Most of the surface-water locations were collocated with the biological and sediment sampling sites to evaluate the correlation between radionuclides and metals detected in those media.

Some surface-water samples were collected at collocated areas along with sediment, fish, and benthic macroinvertebrate samples. The following sections describe the techniques used for the surface water sampling. Sampling was conducted in accordance with SOP SW.06, Surface Water Sampling, SOP SW.17, Pond and Reservoir, other related and relevant SOPs, and the RFI/RI Final Work Plan for OU 3, unless otherwise noted.

Summary of Data Collection Activities

Starting in May and June 1992, surface water samples were collected from the drainages on several occasions at OU 3. Four surface water locations were sampled: Walnut Creek, Dry Creek, Valley Ditch, and Broomfield Ditch. Additional sampling of the drainages took place in July 1992. These surface water samples were collocated with biotic samples. Walnut Creek, Woman Creek, and Big Dry Creek were also sampled again. An attempt to sample Walnut Creek and Woman Creek in October 1992 was unsuccessful because the drainages were dry. Instead, samples were collected from Coal Creek and Big Dry Creek in October 1992.

Standley Lake, Great Western Reservoir, and Mower Reservoir were sampled in July, September, and October 1992. The samples collected from the three reservoirs in July and October were collocated with the sediment and biota samples (fish and benthic macroinvertebrates). Additional samples (not collocated with biota samples) were collected by the U.S. Geological Survey (USGS) from August through September 1992. These samples were collocated with the sediment core samples also collected by the USGS. The USGS worked in conjunction with the DOE to support data collection activities. Their work is summarized in a Water Resource Investigation Report entitled, "Characterization of Selected Radionuclides in Sediment of Surface Water in Standley Lake, Great Western Reservoir and Mower Reservoir, Jefferson County, Colorado 1992" (in progress).

Sample collection methods followed the DOE SOPs for the collection of surface water. In general, all samples were collected by direct immersion of sample bottles into the surface water.
During surface water sampling, the following *in situ* water quality parameters were collected:

- pH
- Temperature
- Specific conductivity
- Hardness
- Alkalinity
- Turbidity
- Dissolved oxygen

The water quality/sampling activities are described in Subsection 2.3. The following sections describe the specific techniques used for sampling the drainages and the reservoirs.

<u>Drainage Surface Water Sample Collection</u> - Surface water samples were collected from the drainages by direct immersion of sample bottles into the water. However, for the dissolved metals and dissolved radionuclide analyses, the surface water was initially collected into a precleaned stainless steel bowl. The water was then drawn through a 0.45-micron barrel filter using a peristaltic pump. A separate filter was used for each sample collected. The resulting sample was collected directly into the respective sample bottles. For custody purposes, samples were properly labeled and sealed in the field. In addition, chain-of-custody forms were completed at the time of sampling. Samples were then embedded in ice inside a cooler and transported to the sample management trailer to be packaged for shipping. A summary of the collection of drainage surface water samples is presented in Appendix C.

<u>Reservoir Surface Water Sample Collection</u> - Reservoir surface water samples were a composite of depth-integrated samples collected from each location. Prior to sampling activities, the location was characterized by analyzing in situ water quality parameters consisting of dissolved oxygen, pH, temperature, specific conductivity, hardness, alkalinity, turbidity, and total depth. All field parameters were measured and recorded as described in SOP SW.2, Field Measurements for Surface Water Parameters. A dissolved oxygen probe was deployed through the entire depth of the water column at a given sampling location. Dissolved oxygen and temperature readings were collected at frequent intervals to determine if stratification (separation of the water column by distinct temperature layers) was present. Appendix C summarizes the reservoir surface water samples collected.

If stratification was not present, reservoir water samples were composited from the surface, mid-depth, and bottom. Samples were collected using a 2-liter Van Dorn depth sampler. Samples from the surface, mid-depth, and bottom were composited into a precleaned polyethylene carbuoy. Sample jars were then directly filled from the carbuoy, except for the dissolved metals and dissolved radionuclide portions. The samples for dissolved constituents were drawn through a 0.45-micron barrel filter with the use of a peristaltic pump.

Differences in temperature and dissolved oxygen content resulted in distinguishable stratified layers. Because the water chemistry and the bioavailability of COCs may be influenced by the stratification, a single grab surface water sample was collected from each identified layer. Stratification was observed at only one location (SW03592) within Standley Lake. As a result, samples were collected from a depth of 0 to 1 foot (SW07026CH), 25 to 30 feet (SW07028CH), and 75 feet (SW07029CH) (see Figure 2-2). No other stratification was identified during the surface water sampling.

Sample of lake-bottom water were collected in conjunction with those of lake bottom sediment cores at all three reservoirs. Five bottom-water samples were collected from Great Western Reservoir (August 31 through September 2 and 15, 1992), four from Standley Lake (September 8 and 9, 1992), and three from Mower Reservoir (September 14, 1992). The bottom-water samples were collected approximately 1 to 1-1/2 feet from the bottom of the reservoir using the Van Dorn sampler (see Appendix C for sample numbers).

At Mower Reservoir, surface-water samples were collected for VOC analyses. The VOC samples were collected using a 4-foot teflon bailer with a check valve on the top and a controlled-flow check valve at the bottom. The bailer was lowered vertically into the water and allowed to fill with water. After removing the bailer, the 40-ml glass vial was filled directly from the bottom of the bailer using the controlled-flow valve to minimize volatilization.

Analyses Performed

The primary chemicals of concern in the surface water samples are radionuclides (gross alpha/beta, plutonium-239, -240, uranium-233, -234, uranium-235, uranium-238, and americium-241, and tritium in Great Western Reservoir) and metals (full Contract Laboratory Program [CLP] TAL including cyanide). At Mower Reservoir, VOCs were also analyzed. Both dissolved and total analyses were performed for both total and dissolved radionuclides and metals.

In addition to the above analytes, the surface-water samples were analyzed for the following constituents:

- Atrazine
- Simazine
- Oil and Grease
- Nitrate and Nitrite (as nitrogen)
- Total phosphorus
- Orthophosphate (as phosphate)
- Ammonia
- Hydrogen sulfide (H_2S)
- Sulfate
- Bicarbonate as calcium carbonate ($CaCO_3$)
- Carbonate
- Chloride (Cl)
- Fluoride (F)
- Total dissolved solids (TDS)
- Total suspended solids (TSS)

Refinements to the Work Plan

Table 2-1 summarizes the proposed activity compared to the work that was actually performed. Most of the refinements to the OU 3 Work Plan pertaining to the surface water sampling were described in TM No. 1 and were enacted because of the intermittent flow conditions present in the drainages. Other refinements include the following:

- Analysis of surface-water samples for oil and grease, and hydrogen sulfide. These analyses were not specified in the OU 3 Work Plan but were performed to be consistent with analyses from other OUs and with SOPs for surface-water sampling.

- Reservoir surface water samples were collected in July, September, and October and did not occur during the high and low reservoir capacity as proposed in the Work Plan. Based on historical data for Indiana Street and for the Standley Lake Cities (Westminster, Northglenn, and Thornton), differences in concentrations were not observed.

2.3.2 Water Quality Characterization

Objectives

The purpose of the OU 3 surface water quality characterization was to obtain information pertaining to site-specific water quality. For the surface water sampling performed in July and October 1992, when sediment and biota sampling efforts occurred, an initial *in situ* measurement of water quality parameters was conducted. The parameters measured include:

- pH
- Temperature (°C)
- Alkalinity (mg/L $CaCO_3$)
- Hardness (mg/L $CaCO_3$)
- Turbidity (NTU)
- Dissolved oxygen (mg/l)
- Conductivity (umhos/cm)

The objectives of the water quality sampling included the following:

- To characterize the water quality of each surface water, sediment, and biota sampling location

- To observe temporal fluctuations in water quality

- To correlate results of surface water and sediment sample analyses to water quality characteristics to evaluate bioavailability of chemicals of concern (where applicable) for the Ecological Evaluation (EE)

The water quality characterization activities are in accordance with SOP SW.02 Field Measurement of Surface Water Field Parameters, other related and relevant SOPs, and the OU 3 Work Plan, unless otherwise noted.

Summary of Data Collection Activities

Water quality information was collected from each surface water, sediment, and biota sampling station. In general, water quality information was gathered prior to each surface water sampling event. Temperature readings were taken in conjunction with dissolved oxygen, pH, and conductivity. Each instrument was dependent upon temperature to obtain accurate readings for its respective water quality measurements. The final temperature recorded was based on the consistent reading between the three instruments.

The hardness and alkalinity HACH test kits were used following manufacturer directions. Resulting data from both measurements are reported in units of mg/l $CaCO_3$.

Analyses Performed

No laboratory analyses were requested. Water quality sampling was based on *in situ* instrument readings.

Refinements to the Work Plan

The collection of water quality information was performed as defined in the OU 3 Work Plan.

2.3.3 Sediment Investigation

The sediment investigation consisted of sampling sediments in drainages and reservoirs in OU 3. A total of 282 sediment samples (excluding quality control samples) were collected from 118 sample locations. Figures 2-3, 2-4, and 2-5 present the sediment sampling locations for IHSSs 200, 201, and 202, respectively. In the reservoirs, sediment locations were selected to correspond to sediment samples collected by Dow Chemical in 1984. Five types of samples were collected:

- Grab samples from drainages (24 locations)
- Grab samples from within the reservoirs (45 locations)
- Grab samples from the near-shore sediments surrounding the reservoirs (34 locations)
- Vertical cores from the near-shore sediments (8 locations)
- Vertical profile samples from the reservoirs (12 locations)

Objectives

The purpose of the OU 3 sediment sampling was to evaluate the presence, concentrations, and distribution of potential contaminants associated with these materials. The primary objective of the sediment sampling was to collect sediment grab samples to characterize the potential lateral extent of surficial sediment contamination and to collect sediment core samples to characterize the potential vertical extent of contamination in lake bottom sediments.

As part of the EE, sediments were collected in OU 3 drainages and reservoirs to evaluate potential relationships between contaminant levels in abiotic and biotic media, particularly benthic macroinvertebrates and fishes.

The following summarizes the sampling of sediment grabs (drainages and reservoirs), reservoir sediment core, and nearshore sediment sample (grab and core) collection activities conducted for OU 3. These activities were performed in accordance with SOP SW.06 Sediment Sampling, SOP SW.17 Pond, and Reservoir Bottom Sediment Sampling, other related and relevant SOPs, and the OU 3 Work Plan, unless otherwise noted.

Summary of Data Collection Activities

Sediment Grab Sampling - Sediment grab sampling took place in May and June 1992 in the drainages and along the exposed shores of the reservoirs (near-shore sediment sampling). Twenty-four drainage locations were sampled and 34 near-shore grab samples were collected.

Additional sediment grab samples were collected in July 1992 in three OU 3 drainages (Woman Creek, Walnut Creek, and Big Dry Creek) and in three reservoirs (Great Western Reservoir, Mower Reservoir, and Standley Lake) as part of the EE. Samples were collected at one location on each drainage. Three locations were sampled in Mower and Great Western Reservoirs and four locations were sampled in Standley Lake. These sample locations were resampled in the reservoirs in the Fall of 1992 from September 29 to October 13. These sediment sampling locations were collocated with the surface-water sampling locations. The drainages were not sampled in the Fall of 1992 because virtually all flow had ceased by September. Figures 2-3, 2-4, and 2-5 depict sampling locations at OU 3 drainages and reservoirs.

An extensive sediment grab sampling effort was conducted from August 27 to September 10, 1992 for the purpose of evaluating the potential lateral extent of contamination in the lake bottom sediments. Seventeen locations were sampled at Standley Lake, 15 at Great Western Reservoir, and four at Mower Reservoir. The sampling locations at Standley Lake and Great Western Reservoir were collocated with randomly selected sites sampled in the Rocky Flats 1983/1984 sediment sampling studies (Rockwell, 1984).

Sampling of OU 3 drainage and reservoir sediments was conducted using a petite Ponar dredge or stainless steel scoop. When sampling drainages, the sampling personnel waded into the water to the designated location and slowly lowered the device to the stream bottom. Once in place, the jaws of the dredge were tripped to enclose the sample. Two to three subsamples were collected from each sampling location by moving upstream 2 to 3 feet. The contents of each filled dredge were emptied into a decontaminated stainless steel bowl and thoroughly homogenized before being transferred into sample containers. Sediment sampling in reservoirs was similar except that the dredge was lowered to the bottom of the reservoir from the side of a boat. Additional subsamples were collected from reservoirs by sampling alongside the boat every few feet, emptied into a decontaminated stainless steel bowl, and thoroughly homogenized. Ambient water was used to rinse the dredge and dislodge any sediment adhering to the sampler.

Bottom-sediment grab samples were collected from predetermined locations within the reservoirs. Surveyed sampling locations were coordinated with sites sampled in the Rocky Flats 1983/1984 sediment sampling studies (Rockwell, 1984). The bottom-sediment grab samples were collected using an Eckman dredge. The Eckman dredge sampling was conducted using the same methodology as the Ponar sampler.

Appendix C lists the corresponding sample numbers for each stream and reservoir sampling location.

Sediment Core Sampling - A total of 12 locations were sampled for sediment cores in the three reservoirs from August 31 to September 15, 1992. Four locations were sampled in Standley Lake, five in Great Western Reservoir, and three in Mower Reservoir. Figures 2-3, 2-4, and 2-5 present the coring locations in each reservoir. Sample locations were chosen either in deep portions of the reservoir (zones of accumulation) or in reservoir bays (zones of transport and deposition). At each reservoir, one core was collected near the dam structure where the sediments are usually the thickest. Cores were also collected in the center of each reservoir somewhere near the original stream channel, and in the deltas where the main tributaries flow into each reservoir. Two adjacent cores were collected at each location; one for chemical analysis and a second for physical description. A summary of sediment core samples is presented in Appendix C.

The cores were collected with a gravity-driven piston coring device that consists of a galvanized steel weight stand with fins, an attached galvanized steel core barrel, driving weights, galvanized couplings, polyvinyl chloride (PVC) finger assembly, hose clamps, 2.6-inch-diameter polybutyrate core liners, and a PVC piston valve. Once fully assembled, the corer was attached to a steel cable reel anchored to the bow of the boat and lowered into the water within 20 feet of the reservoir bottom. The corer was allowed to free-fall to the reservoir bottom to obtain maximum sediment core recovery. In shallow waters, such as in Mower Reservoir, the corer was allowed to free-fall from the water surface to get enough momentum to penetrate the bottom sediment. The core sampler was reeled to the water surface and the core liner was removed from the core barrel and end caps were secured on both ends. The liner was properly labeled and stored in a cold box on the boat for transport back to shore for core extrusion and description. The above procedure was duplicated for collection of the second core. Core lengths for all cores collected ranged from a maximum of 34 inches near the dam at Standley Lake (SED08192) to 8 inches at the Woman Creek bay site at Standley Lake (SED08292). In Great Western Reservoir, the core lengths ranged from 10 inches at the Walnut Creek Bay site (SED08592) to 28 inches at the site near the dam (SED09192). In Mower Reservoir, the core length ranged from 12 inches (SED09092) to 20 inches (SED08992). The short core recoveries could be due to composition of bottom sediments, lack of sediment deposition, or insufficient water depth for adequate penetration of the gravity corer.

The core collected for chemical analysis was brought back to shore for extrusion and containerization. After siphoning the water off the head of the core, the core was extruded in 2-inch segments by manually pushing the sediment core with an extrusion rod. Two-inch segments were pushed into 2-inch cutting sleeves and cut with a PVC plate. The sample was then homogenized and distributed to the sample containers.

The core collected for physical description was described in accordance with SOP SW.17 with the core extruded horizontally onto a table. The core material was photographed and qualitatively described in terms of color, texture, and composition.

During the nearshore sampling, vertical cores were also collected at some of the grab sample locations. Along the Standley Lake shoreline, four vertical core samples were collected. At Great Western Reservoir and Mower Reservoir, vertical core samples were collected at three and at one location, respectively. At each core location, samples were collected from 0 to 1 inch, 1 to 2 inches, 2 to 3 inches, 3 to 4 inches, 4 to 5 inches, and 5 to 6 inches.

Analyses Performed for Sediment Sampling

The primary contaminants of concern in the sediment grab samples are radionuclides (gross alpha/beta, plutonium-239, -240, americium-241, uranium-233, -234, uranium-235, uranium-238). TAL metals were also analyzed at each location. Ten percent of the grab samples (10 samples) were also analyzed for TOC, specific gravity, and grain size. At Mower Reservoir, the sediment samples were also analyzed for VOCs. At Great Western Reservoir, the analyses included tritium. In addition, a portion of the sediment grab samples were analyzed for cesium-137, and strontium-89, -90.

The chemical analytes of the reservoir sediment cores include radionuclides (gross alpha/beta, plutonium-239, -240, americium-241, uranium-23, -234, uranium-235, uranium-238, cesium-137, and polonium-210), TAL metals, and cyanide. Analyses for cesium-137 and polonium-210 are for radioactive dating of the sediment cores; they are not contaminants of concern. The near-shore vertical core samples were analyzed for plutonium-239, -240, americium-241, and uranium isotopes.

Refinements to the Work Plan

The sediment sampling activities proposed in the OU 3 Work Plan consist of sampling drainages, reservoirs, and near-shore sediments. As stated in TM No. 1, because of actual field conditions sediment locations varied from the OU 3 Work Plan.

The refinements to the work plan for the nearshore sediment sampling were as follows:

- Three additional vertical core samples were collected at Standley Lake and two additional vertical core samples were collected at Great Western Reservoir. The additional samples were collected near the waterline to allow for the comparison on how radiological concentrations at the sediment surface vary through the reservoir and to provide additional information for evaluating the nature and extent of contamination. The two additional vertical reservoir core locations in Great Western Reservoir were added to verify elevated plutonium activity detections in sampling performed by the City of Broomfield after the OU 3 Work Plan had been approved.

- Some of the nearshore sediment samples were analyzed for strontium-89, -90 and cesium-137. These analyses were not specified in the work plan.

For the sediment grab samples collected in streams and ditches the following adjustments were made:

- Ten sediment locations were specified in the OU 3 Work Plan for drainages associated with Great Western Reservoir (Walnut Creek, portions of Church Ditch, and Broomfield Diversion Ditch) but only eight locations were sampled. Fewer samples were collected based on field conditions observed.

- Fourteen sediment locations were specified in the OU 3 Work Plan for drainages associated with Standley Lake (Woman Creek, Church Ditch, Smart Ditch, Big Dry Creek, and Coal Creek) but only 11 locations were sampled. Fewer samples were collected, based on field conditions observed.

- Some of the sediment drainage samples were analyzed for strontium-89, -90 and cesium-137. These analyses were not specified in the OU 3 Work Plan.

The sample sizes for each of the drainages meet the 80 percent power specified in the OU 3 Work Plan (subsection 6.3.1 of the Work Plan).

For the reservoir sediment samples, the following adjustments to the work plan were made:

- Eighteen reservoir sediment samples in Standley Lake were proposed in the OU 3 Work Plan, but 21 locations were sampled.

- In Great Western Reservoir, 15 grab samples and 3 core samples were proposed in the OU 3 Work Plan. During field sampling, 18 locations were sampled for sediment grab samples and five vertical cores were collected. The additional samples were collected to evaluate recent detections of plutonium from sampling performed by the City of Broomfield that occurred after the Work Plan was approved.

- In Mower Reservoir, two additional grab sample locations were sampled than specified in the work plan.

- Core recovery of a full 30 inches was not possible at every location, possibly due to composition of bottom sediments, lack of sediment deposition, or insufficient water depth for adequate penetration of gravity corer.

- Because of the shallow water depth in Mower Reservoir, the gravity core sampler was not used. At the time of sampling, the water depth in Mower Reservoir was less that 6 feet. The gravity core sampler used in Standley Lake and Great Western Reservoir was therefore not practical for use in Mower Reservoir. The gravity core sampler was manually driven into the sediments in Mower Reservoir.

- Vertical core samples were analyzed for polonium-210, cesium-137, and metals. These analyses were not specified in the work plan. The polonium-210 and cesium-137 analyses were included to help age-date the core. Metals were added to evaluate redox conditions at the sediment/water interface, assess mobility of metals, evaluate movement of metals from sediment to the water column, and compare results to previous studies.

The OU 3 Work Plan proposed a total of 10 vertical profile sediment samples to be collected from the three reservoirs. As a result of a sediment core site locating meeting, 5 core locations were selected at Standley Lake, 4 at Great Western Reservoir, and 3 at Mower Reservoir. Two-inch segments were cut from the entire core length. The top 6 inches was not considered compacted (as presented in the work plan) and was sampled in 2-inch segments for the entire length of core recovered. Cesium-137 and polonium-210 were added to the list of analytes for age-dating purposes. In addition, metal analyses were requested for the core samples. Core recovery of 30 inches was not achieved at every location. At Mower Reservoir, a sampler was designed to collect the sediment samples because the specified gravity sampler did not work in shallow water.

Table 2-1 summarizes the proposed sampling effort compared to the work that was actually performed.

2.4 GROUNDWATER INVESTIGATIONS

The groundwater investigation consisted of installing two monitoring wells, one in the vicinity of Great Western Reservoir, and one near Standley Lake (Figure 2-6). After completion of the groundwater monitoring wells, the wells were developed and prepared for sample collection. The objectives of the groundwater sampling, summary of data collection activities, analyses requested, and refinements to the work plan are presented in the following subsections.

2.4.1 Objectives of Groundwater Sample Collection

The purpose of the groundwater investigation was to gain an understanding of the hydrogeology in the vicinity of Great Western Reservoir and Standley Lake (Figure 2-6) and to assess potential impacts to groundwater from potential contaminants dispersed offsite to OU 3 through the reservoirs. Groundwater sampling also identified potential contamination from sediment/groundwater interactions and surface water/ groundwater interactions. The following sections describe the techniques used for the groundwater sampling effort. The procedures employed for the drilling, logging, installation, completion, development, and groundwater sampling were all in accordance with the current DOE ER, and the OU 3 Work Plan, unless otherwise noted.

2.4.2 Summary of Data Collection Activities for Groundwater

In December 1992, two monitoring wells were drilled and installed for the OU 3 project. One monitoring well (49292) is located at the base of the dam at Standley Lake, and the other monitoring well (49192) is located at the base of the dam of Great Western Reservoir. Figure 2-6 presents the location of the two

Table 2-3
OU 3 Groundwater Monitoring Well Completion Summary

	Well Number	
	49192 (Great Western)	49292 (Standley Lake)
Total Depth	40 feet	46 feet
Screen Interval	24 to 34 feet	29 to 44 feet
Gravel Pack Interval	18 to 39 feet	24.5 to 46 feet
Ground Elevation	5,544.44 feet	5,399.75 feet

groundwater monitoring wells installed during the OU 3 field investigation. Each well was drilled by a rotary drill, employing a hollow-stem auger. The auger flights were 6 feet in length, and 8 inches in diameter, fabricated with 2-inch-I.D., Schedule 40 PVC pipe. The specifications for well completion required a gravel pack of No. 16-40 silica sand, a minimum of 2-foot bentonite seal above the gravel pack, and a cement grout seal mixed with 5 percent bentonite powder. The screen is 2-inch-I.D., Schedule 40 PVC. The SOPs required a 2-foot stick up, and steel protective casing around the PVC stick up. Table 2-3 presents the completion information for each monitoring well.

Groundwater samples from the two monitoring wells were collected monthly beginning in January 1993. Prior to any sample collection, the two monitoring wells were developed and prepared for sample collection.

During groundwater sample collection activities, the following *in situ* water quality parameters were measured:

- pH
- Temperature
- Specific Conductance

- Turbidity
- Dissolved Oxygen

A summary of the analytical data for samples collected from the wells, including the QA/QC samples, is presented in Appendix A.

Methods used for groundwater sampling followed the directives of DOE SOPs. In general, all samples were collected by bailing water from the well and placing it in a stainless steel container. The water was then extracted from the container using a peristaltic pump. However, the monitoring well at Standley Lake is an artesian well, and the procedures to collect groundwater samples are performed in a manner not specified in the DOE SOPs. The following sections describe the specific techniques that were followed.

Groundwater Sampling at the Great Western Reservoir Monitoring Well

Prior to any sample collection, the monitoring well was purged of three casing volumes of water to ensure representative samples of the aquifer. Groundwater samples were collected by using a 3-foot bailer to extract water from the monitoring well. The water was then collected in a stainless steel container. Water was extracted from the stainless steel container using a peristaltic pump and placed in the appropriate sample containers. Any samples that required filtering were drawn through a 0.45-micron barrel filter using the peristaltic pump and placed directly in the sample container. Samples were properly labeled and sealed in the field for custody purposes. In addition, chain-of-custody forms were completed at the time of sampling. Samples were then embedded in ice and transported to the sample management trailer to be inventoried, packaged, and prepared for shipping.

Groundwater Sampling at the Standley Lake Monitoring Well

Groundwater samples were collected with a different method in the monitoring well at Standley Lake because it is an artesian well. Prior to sample collection, the well was allowed to flow freely until three casing volumes had flowed from the well. After the appropriate number of casing volumes were extracted, the well was allowed to flow and water was collected in a stainless steel container. Water was extracted from the stainless steel container using a peristaltic pump and placed in the appropriate sample containers. Any samples that required filtering were drawn through a 0.45 micron barrel filter using the peristaltic pump and placed directly in the sample container. Samples were properly labeled and sealed in the field for custody purposes. In addition, chain-of-custody forms were completed at the time of sampling. Samples were then embedded in ice and transported to the sample management trailer to be inventoried, packaged, and prepared for shipping.

2.4.3 Analyses Performed for Groundwater Sampling

Groundwater samples collected from the Great Western Reservoir monitoring well and the Standley Lake well were analyzed for plutonium, americium, uranium, major cations/anions, nitrates, total metals, and dissolved metals. Water level measurements were made on a monthly basis for one year to identify possible seasonal fluctuations in the groundwater table elevation.

2.4.4 Refinements to Work Plan

The OU 3 Work Plan specified that the groundwater monitoring wells would be sampled quarterly for 1 year and analyzed for plutonium, americium, uranium, and cations/anions. Sampling on the OU 3 wells exceeded this requirement, in fact, during the first year following installation (December 1992), they were sampled eight times (January, April, May, June, July, August, September, and November 1993). Samples were collected monthly from April through September to ensure there would be several groundwater events to incorporate into the Draft RFI/RI Report. Groundwater samples were analyzed for TAL metals to be consistent with analyses from the comprehensive site environmental monitoring. The barometric pressure was not recorded during field sampling. Additional groundwater samples were collected from the OU 3 monitoring wells in January, May, August, and October 1994 and in March 1995. The samples were analyzed for the same parameters listed above.

2.5 AIR QUALITY AND METEOROLOGICAL INVESTIGATIONS

There are two components of the air program at OU 3: (1) the wind-tunnel study and (2) the air sampling program. The purpose of the air program is to characterize the health impact from dispersion of potentially-radioactive sediments and soils. Measuring the wind erosion on the shoreline of the reservoirs and on vegetated terrain is difficult; therefore, a combination of air sampling and a special wind-tunnel study was selected as the method of characterization. The air pathway has been identified historically as one of the primary exposure pathways of concern.

2.5.1 Wind-Tunnel Study

The wind-tunnel study consisted of performing tests using a portable wind tunnel to quantify wind suspension emissions of particulate matter from the soils and sediments of OU 3. The tests were conducted at three locations: (1) along the shore of Standley Lake, (2) along the shore of Great Western Reservoir, and (3) terrestrial sites between the two reservoirs.

Objectives

The primary objective of the wind tunnel study was to collect site-specific resuspension potential data. This information is used in the HHRA to evaluate exposure through inhalation. The specific objectives for the portable wind tunnel studies are as follows:

- Characterize and quantify resuspendable soil and sediment particulates from offsite areas that contain radionuclides.

- Produce data and information that specifically support an evaluation of long-term public health impacts resulting from exposure to these sources.

Summary of Data Collection Activities

Two types of tests were performed in the wind tunnel study: (1) screening tests and (2) comprehensive tests. The screening test included an emission measurement for a 20-minute sampling period with the wind tunnel operating near its flow capacity. The purpose of the screening test was to bracket the worst-case erodibility of representative portions of the study area with different surface characteristics (soil texture, presence of nonerodible elements, etc.). Tests were performed under undisturbed and disturbed surface conditions.

During the comprehensive tests, the wind tunnel was operated at approximately one-third and two-thirds of the range between the threshold velocity (the velocity representing the onset of wind erosion) and the capacity of the wind tunnel. At each flow rate, a 2-minute test was followed by an 8-minute test to ensure that the decay in the emission could be estimated and the erosion potential calculated directly.

Table 2-4
Summary of Wind Tunnel Studies Performed

	Screening Test			Comprehensive Test	
Location	U	D	Dx	D	Dx
S-1					
S-2					
S-3	X	X			
S-4	X	X	X		X
S-5					
S-6	X	X			
T-1	X	X		X	X
T-2	X	X		2	X
T-3	X	X		X	X
T-4	X	X			

S = Shoreline location
T = Terrestrial location
U = Undisturbed
D = Disturbed
Dx = Extra Disturbed
2 = Two Tests performed under disturbed conditions

Table 2-5
Wind Tunnel Test Conditions

Run No.	S/C**	Site ID	U/D/Dx*	Tunnel CL Wind Velocity (mph)	Friction Velocity	Equivalent Wind Velocity at 10-m (mph)
RF-1	S	S-6	U	39.7	98	110
RF-2	S	S-6	D	30.3	83	85
RF-3	S	S-4	U	34.1	100	96
RF-4	S	S-4	U	28.9	95	81
RF-5	S	S-4	Dx	32.0	54	90
RF-6	C	S-4	Dx			
a				17.1	24	48
b				17.1	24	48
c				23.7	34	67
d				23.7	34	67
RF-7	S	T-1	U	34.3	220	96
RF-8	S	T-1	D	33.2	200	93
RF-9	S	T-3	U	25.3	120	71
RF-10	S	T-3	D	32.5	100	91
RF-11	S	T-2	U	25.4	140	71
RF-12	S	T-2	D	30.6	100	86
RF-13	C	T-2	D			
a				23.1	100	65
b				23.1	100	65
c				27.8	120	78
d				27.8	120	78
RF-14	S	S-3	U	32.2	59	90
RF-15	S	S-3	D	34.2	110	96

Table 2-5 (Continued)

Run No.	S/C**	Site ID	U/D/Dx*	Tunnel CL Wind Velocity (mph)	Friction Velocity	Equivalent Wind Velocity at 10-m (mph)
RF-16	S	T-4	U	37.1	180	100
RF-17	S	T-4	D	33.6	120	94
RF-18	C	T-1	D			
a				24.0	93	67
b				24.0	93	67
c				28.1	110	79
d				28.1	110	79
RF-19	C	T-1	Dx			
a				23.7	60	67
b				23.7	60	67
c				27.7	70	78
d				27.7	70	78
RF-20	C	T-2	D			
a				27.0	100	76
b				27.0	100	76
c				31.1	110	87
d				31.1	110	87
RF-21	C	T-2	Dx			
a				24.0	71	67
b				23.8	71	67
c				31.0	91	87
d				31.0	91	87
RF-22	C	T-3	D			
a				26.2	100	74
b				26.2	100	74
c				34.0	130	95
d				34.0	130	95
RF-23	C	T-3	Dx			
a				24.2	61	68
b				24.2	61	68
c				34.2	86	96
d				34.2	86	96

C = Comprehensive test
D = Disturbed
Dx = Extra disturbed
S = Screening test
U = Undisturbed

A total of 15 screening tests and 8 comprehensive test series (31 individual tests) were performed during the wind-tunnel study. The tests occurred from June 2 through June 10, 1993 and from July 8 through July 10, 1993. Testing occurred at three locations along the reservoir shorelines (S-3, S-4, and S-6) and at four terrestrial locations (T-1 through T-4) as shown in Figure 2-7. Table 2-4 summarizes the wind-tunnel studies performed. Table 2-5 summarizes the test conditions (e.g., wind velocity) at each location.

Analyses Performed for Wind Tunnel Study

The wind tunnel filters were sent to the laboratory for analysis of plutonium-239, -240, americium-241, uranium-233, -234, uranium-235, and uranium-238.

Refinements to Work Plan

The OU 3 Work Plan states that two screening tests would be performed at each location. However, no screening locations were performed at S-1, S-2, or S-5 because during the second sampling event from July 8 through July 10, 1993, the water levels for both Standley Lake and Great Western Reservoir were high, and covered these shoreline sites.

At location S-4, three screening tests were performed: (under undisturbed, disturbed, and extra disturbed surface conditions), instead of two screening tests as stated in the Work Plan. An additional screening test was performed at this location because there was a large accumulation of uncompacted silt overlying the rocky sediment, thus justifying an extra disturbed test.

Sample filters were not packaged in glassine envelopes for shipment to the field. This SOP requirement applies to air sampling procedures and was not appropriate for the wind tunnel. The sample filters were packaged in numbered file folders and the substrates were separated by wood and cardboard spacers and then stacked in plastic carriers. The glassine envelopes were used only to ship the exposed filters to the laboratory. The substrates were returned to the laboratory in plastic carriers.

2.5.2 Air Sampling

As part of the OU 3 air sampling program, three ultra high-volume (approximately 500 cubic feet per minute) air monitoring stations were installed in the vicinity of Standley Lake to characterize the potential for dispersion of plutonium-contaminated soils and sediments. One ultra high-volume air monitor was installed near the southeast portion of Standley Lake (at the southwest corner of the intersection of 86th Avenue and Kipling Street) to represent a residential receptor. This monitoring station has been operated during daylight hours only (due to noise level complaints) since May 1, 1995. One air monitor was installed northwest of Standley Lake (100th Avenue), and one air monitor was installed near the southwest portion of Standley Lake (north of 88th Avenue). These two monitoring station sites were selected to represent recreational receptors and have been operational continuous since July 1995.

The air sample filters from all three monitoring stations will be analyzed for concentrations of plutonium, americium, and uranium. No data are available for the three air monitoring stations at this writing. It is anticipated that approximately 6 months of air monitoring data will be presented in the final version of the RFI/RI report for use in the OU 3 risk assessment.

Refinements to Work Plan

Two meteorological monitoring stations were installed to provide ambient environmental data (temperature, barometric pressure, wind speed, wind direction, and humidity) for air dispersion modeling for the risk assessment. One station is located east and downwind of Rocky Flats within the City of Westminster Open Space. The second meteorological monitoring station is located with the ultra high-volume air sampler installed near the southeast portion of Standley Lake.

The OU 3 Work Plan specified that the ultra high-volume air samplers will operate continuously for approximately one year. Due to the presence of nesting Bald Eagles in the Standley Lake area and land access agreement delays, the installation of the air and meteorological monitoring stations was not completed until July 1995. One of the air samplers became operational in May 1995 (the station located at 86th and Kipling, which represents a residential receptor). The remaining two air samplers became operational in July 1995. It is anticipated that approximately 6 months of the ultra high-volume monitoring data will be available for use in the OU 3 risk assessment.

2.6 ECOLOGICAL INVESTIGATIONS

Ecological investigations consisted of field sampling for biota for ecological parameters in aquatic and terrestrial ecosystems in order to assess the PCOC effects where possible. The field sampling provided comprehensive data and information on biological and ecological field characteristics for OU 3. The objectives of the ecological field sampling program were:

- Characterize the ecosystem and biological receptors in OU 3
- Determine the types, forms, and quantities of contaminants of concern within OU 3 (primarily completed by the RFI/RI site characterization)
- Identify the complete exposure pathways between contaminant sources and biological receptors
- Quantify, where possible, the migration of the PCOCs through the ecosystem and the uptake of those chemicals by receptors
- Conduct toxicity tests and measure bioaccumulation of PCOCs in biota to verify exposure and evaluate potential adverse effects

The field sampling procedures were developed following protocols recommended by the EPA (1987, 1988, 1989b, 1989c)and the U.S. Fish and Wildlife Service (1981a, 1981b). Standard Operating Procedure (SOP) 5.13A, "Development of Field Sampling Plans for Biological Sampling during the Field Activities," was used to develop sampling procedures. This SOP included procedures for sampling organisms. All ecological data and sample collection followed the procedures provided in the Ecology SOP (Volume V) (DOE, 1991a), with appropriate site-specific addenda.

The field sampling program began with an initial qualitative field survey conducted in May and June 1992. The terrestrial sampling followed with a single quantitative field sampling event in mid-Summer 1992. Aquatic sampling followed with two quantitative field sampling events, one in mid-summer and another in early Fall 1992. The quantitative sampling was conducted by taxonomic group: for vegetation, small mammals, periphyton, benthic macroinvertebrates, and fish. During the quantitative sampling efforts, the sampling teams recorded qualitative observations of habitat and site conditions to assist in interpretation of the field data collected during the program.

2.6.1 Terrestrial Biota

Both qualitative and quantitative sampling was performed to evaluate terrestrial biota associated with OU 3.

Objectives

The purpose and objectives of the terrestrial field sampling program were to characterize the terrestrial biota, sample for biotic components, and measure for bioaccumulation of PCOCs. Qualitative surveys were followed by quantitative sampling of terrestrial ecosystems and biota. The quantitative surveys were conducted to characterize the ecosystems and measure the ecological consequences of contaminants released from the source areas.

Summary of Data Collection Activities

The field sampling program for terrestrial communities at OU 3 locations was aimed at sampling grassland vegetation, and small mammal populations. The station locations selected for terrestrial sampling are shown in Figure 2-8, and details of the sampling program are summarized in Table 2-1. The station locations and the selection of the vegetation types sampled were consistent with the results of the early season qualitative surveys and, when possible, corresponded to soil trenches and surficial-soil sampling locations for site characterization. All sample locations for productivity and tissue sample collection were collocated with soil trenches and surface-soil sampling. Additional abiotic factors were recorded for each tissue sample location.

<u>Qualitative Terrestrial Studies</u> - The reconnaissance and qualitative field surveys provided terrestrial characterization information to refine the types of quantitative field surveys to be performed. Prominent features and general observations of OU 3 were recorded in the reconnaissance field surveys including topography, drainages, soils, vegetation, animals, wetlands, and the relationship of these features to land use. Qualitative vegetation, bird, and mammal surveys followed protocols in Sections EE.7.0, EE.9.0, and EE.10.0 in the Ecology SOP (DOE, 1991a).

The initial qualitative field surveys were conducted in the late spring and early summer after the start of the growing season of grassland vegetation.

The qualitative field surveys provided the following information:

- Physical description and photographs of all sampling sites
- Identification, collection, and initial inventory of plant and animal species
- Vegetation/habitat map and descriptions of principal habitats, land use patterns, and vegetation characterization

- Qualitative descriptions of wetland and prairie grassland communities, including identification of dominant and subdominant species

- Relative abundance of key terrestrial receptors

- General observation of the vegetation, small and large mammals, predators, birds, and signs of animals (tracks, scat, skeletons, burrows, etc.)

- Confirmed lack of critical or sensitive habitats, and threatened or endangered species

- Confirmed principal exposure pathways and principal food-chain relationships to further define the conceptual model.

The proposed quantitative sampling locations were identified and staked. At sampling locations close to the site boundaries, plants and animals were examined for obvious signs of impacts or effects of contaminants were examined in plants and animals. Observations on recent biological activities that impeded or increased the movement of soil or waterborne contaminants were noted. In particular, visual surveys were made for prairie dogs, ants, and fissural animals, such as gophers, which bring large amounts of subsurface soil to the surface where it is distributed by wind. Observations were made for badger and fox activities, specifically dens or diggings.

Qualitative surveys for mammals, birds, and reptiles were conducted by systematically driving and walking the area on preselected routes at appropriate times, and by opportunistic sightings during all visits to Rocky Flats. Bird surveys were conducted at dawn and dusk. Records were kept of species and other features observed such as numbers, condition, habitat, and activities. Other evidence of animals or birds including burrows, scat, and nests were recorded. Checklists and forms were prepared prior to the qualitative surveys of animal and plant species to record survey information.

Based on information from the other sites and DOE reports, snow accumulation depressions, and protected slopes on the lee side of windbreaks located downgradient of the source areas are sensitive indicators of contaminant deposition via the air pathway, or may promote accumulation of contaminants by physical processes. These types of areas were located and delineated for later quantitative sampling. Mesic and wetland plant communities in drainages and depressions were too small and scattered to systematically sample, and subject to management controls. Sampling sites for terrestrial tissue collection were selected to represent a gradient of chemical concentration from east to west from the site boundary, and north to south along Indiana Street in OU 3.

<u>Quantitative Terrestrial Studies</u> - Quantitative sampling of terrestrial ecosystems at OU 3 was conducted to complete an inventory of the ecosystems for site characterization and to measure the effects potentially attributable to contaminants released or resuspended from the source areas. The quantitative sampling program included measuring biotic parameters at selected sampling stations and measuring contaminant concentrations in tissue samples. The quantitative sampling supplemented qualitative survey information described above. Qualitative observations continued to be recorded when field biologists were conducting quantitative sampling.

<u>Vegetation</u> - The grassland communities at the sampling locations were measured for plant species composition, cover, and productivity using standardized procedures for site characterization and modified procedures as discussed here for quantitative sampling. These parameters give the best indication of the

structure and function of dryland vegetation. The sampling protocol followed Section EE.10 in the Ecology SOP, except as noted.

Mid-Summer data for vegetation were collected, and tissue samples were collected for analysis at the same time. Data collected were analyzed to assess the following variables:

- Total plant cover
- Cover by perennial grasses, annual grasses, perennial forbs, and annual or biennial forbs
- Cover by individual species
- Richness (number of species)
- Production (standing biomass in grams per square meter [g/m^2] and pounds per acre [lbs/acre])
- Height (in centimeters)

Assuming a gradient in concentrations of PCOCs, with RFETS as the point source, ecological sampling sites coincided (where possible) with locations sampled for surface or subsurface soils. Based on results of the qualitative field surveys conducted in the late spring, 13 locations were chosen to represent the habitat types identified during those surveys. The locations for sampling grassland vegetation corresponded with the soil-sampling locations with additional locations based on grassland vegetation types. Within the sampling area, transects for vegetative cover and clipping plots for productivity were located close to the soil-sampling points or in areas of well-developed vegetation.

Two types of quantitative surveys were used for cover and productivity estimates: (1) point intercept transects for grasslands and, (2) five contiguous round 0.5 m^2 plots for productivity and tissue sample collections. In the intercept transects, plant species were recorded based on the number of species present and information regarding height, condition, and phenology were recorded. For productivity in grasslands, vegetation in 0.5 m^2 plots was clipped to within 1/2-inch of the ground surface, according to the current season's growth by species, or type of species, and bagged for dry weight and tissue analysis. The number of required transects or quadrats for both cover and productivity were determined by a sample adequacy formula. The sample adequacy was determined to be five to eight sample plots.

The transect samples were analyzed for species composition and cover, and the frequency and dominance (importance) values derived. The samples clipped for productivity were collected in bags, oven-dried to a constant temperature, and weighed. The grassland quadrant samples provided species composition, cover, productivity, diversity, and structure of the terrestrial ecosystems. Tissue sample analysis provided data on chemical concentrations in vegetation as an indicator of bioconcentrations.

Biomass samples were placed into labeled paper bags and oven-dried in the bag (104°C for 24 hours), then weighed. Samples collected for tissue analysis followed the sample preparation and packaging specified by the laboratory protocols for the selected analytes and were generally consistent with SOP 1.13. Clipped material not a part of the biomass tissue collection were dried, weighed, and then discarded as nonessential to the study.

Small Mammals - Small mammal populations were surveyed to determine habitat use and relative abundance. For community evaluation, endpoints included:

- Richness (number of species)
- Abundance (number per trapping period) by species
- Mean weight

Small mammals, particularly deermice and microtines, are primary consumers of vegetation and form the basis for the link to the higher levels in the food chain leading to top carnivores. Alternate species, prairie dogs, or pocket gophers, were not collected for tissue analysis because the small mammal collection was adequate for analytical purposes.

Small mammals were collected using live-trapping techniques as described in SOP 5.6. Thirteen locations were collocated with vegetation study plots (Figure 2-8). A 5 x 5 grid of 25 Sherman live traps was positioned at each location, and spaced 5 meters apart, with each trap covered by a sheet metal hood to provide protection against sun and rain. Traps were baited during evenings with a rolled oats mixture (Omalene horse feed), and checked for four mornings. This trapping effort resulted in 100 trap-nights (25 traps for 4 nights) at each of the 13 locations.

Captured animals were marked by hair clipping and released after the following information was recorded: species, weight, sex, reproductive status, age class, if previously marked (a recapture), and trap number. Trapping was performed between July 14 and August 8, 1992, and only during typical (not inclement) weather. All information was recorded on standard data sheets.

Only small mammals were collected for tissue analysis. Collections were made at the 13 small mammal live trapping locations described above (see Figure 2-8). Specimens were kept in coolers in the field, then frozen for storage prior to shipment.

For animals collected for tissue analysis of PCOC content, tissue samples were chilled for as many as 4 hours, and then placed in a freezer until shipped. Labeling, handling, and shipping of small mammals for laboratory analysis were consistent with SOP 1.13. Samples collected for tissue analysis followed the sample preparation and packaging specified by the laboratory protocols for the selected analytes. Appendix A summarizes the mammal samples submitted for analysis.

Other Wildlife Studies

Small Birds - As used in this report, the term "small birds" includes all passerines (perching birds) as well as woodpeckers, swifts, and hummingbirds. Ten locations were sampled on the OU 3 study area (see Figure 2-8). Three 100 x 100 meter contiguous plots were centered on each of these 10 locations. The corners, and central positions along the perimeters of each plot, were marked with a flagged stake. All birds seen or heard within each plot were recorded while walking along plot center lines. Counts were performed during 4-minute time periods. Observations within each of the 3 plots (at each of the 10 locations) were replicated 7 times, for a total of 21 replicates per location. This sample size was based on a predetermined level of precision; namely, 95 percent confidence intervals within 30 percent of sample means for most locations. All counts were performed by the same observer, during mornings (06:30 to 10:45 hours), and only during typical (not inclement) weather. Locations, as well as plots within locations, were alternated each day. A standard data sheet was used to record bird sightings, as well as information on temperature, wind speed, cloud cover, and time of observations. All small bird sampling was performed between June 2 and June 18, 1992.

Raptorial Birds - Sightings of raptors (eagles, hawks, falcons, and owls) were recorded from a vehicle while driving roads in the project area, and during the course of other field activities. The objectives of raptor studies were to obtain a list of the species present on the site, and to obtain an estimate of abundance. Special attention was given to examining large trees for nests, and observing prairie dog colonies for the presence of burrowing owls.

Reptiles and Amphibians - Reptiles and amphibians were searched for throughout the area, with special attention given to moist habitats. Also, snakes were looked for beneath logs and debris, and were identified when found as road kills. As with raptor studies, objectives were to obtain a species list and an estimate of abundance.

Threatened and Endangered Wildlife - Surveys of state or federally-listed threatened or endangered wildlife were an integral part of the studies described above. Based on historical records, agency data bases, and several years of biological studies at Rocky Flats, there could potentially be several Federally listed threatened, endangered, or candidate species that could occur within OU 3; however, very few of these species are residents or regular visitors to the OU 3 area. Listed candidate species known to be regular visitors or residents in OU 3 are the endangered Bald Eagle, ferruginous hawk, Prebles' meadow jumping mouse, and the forktip three-awn plant. The black-footed ferret was a resident in the area in the past, but no confirmed sightings have been reported in Colorado since 1943. Recent plant surveys have been unable to locate two plants of principal concern: the threatened Ute Ladies' tresses and the Federal Category 1 (C-1) Candidate Colorado butterfly plant.

Wintering Bald Eagles have been observed in OU 3 during the November through March period, usually near the western periphery of Standley Lake and north of the lake. The ferruginous hawk foraging areas north and west of Standley Lake generally overlap with the foraging areas used by the Bald Eagle. No Prebles' meadow jumping mice or forktip three-awn plants were observed during the ecological field sampling activities, or plant and animal species surveys conducted prior to specific OU 3 field Activities.

Terrestrial Sampling Matrix - A complete activity summary has been constructed in Appendix C that contains purposes (tissue, quantitative, or qualitative community analysis), analyses, locations and numbers of samples, and a rationale for each taxon.

Analyses Performed

Vegetation samples were analyzed for radionuclides, including Plutonium -239, -240, Americium -241, and total uranium and are summarized in Appendix C because the chemicals were identified as PCOCs to the terrestrial biota (DOE, 1992a).

Refinements to the Work Plan and SOP

Refinements to the quantitative sampling plan resulted from the qualitative survey and a review of data from OU 1. Other general changes were presented in TM No. 1.

Sample procedures followed the OU 3 Work Plan and Section EE.10 in the Ecology SOP with the following exceptions:

1. Five contiguous round plots were sampled at the soil pits locations for a combination of species composition cover, productivity, and plant tissue sampling. All clipped vegetation was composited for each 0.5 square meter plot for weight and tissue analysis.

2. Wetlands were not sampled for quantitative variables because of disturbance and heterogeneity.

2.6.2 Aquatic Biota

Both qualitative and quantitative sampling was performed to evaluate aquatic biota associated with OU 3.

Fish

Objectives of Sampling Program - The purpose of the OU 3 fish sampling was to characterize the fish populations within the OU 3 aquatic systems. Objectives of the sampling efforts included:

- Collecting fish samples to establish assessment and measurement end points for the ecological risk assessment
- Conducting random sampling efforts to adequately characterize species occurrence throughout the areas of study
- Collocating fish sample collection with surface water, sediment, and benthic macroinvertebrate sample collection in order to complete correlative analyses between the sample results
- Conducting tissue analysis for radionuclides and metals to determine food chain effects and dose estimates for higher trophic levels.

Activities performed during the sampling periods to complete the above described objectives included:

- Backpack electroshocking of stream sample location areas
- Boat electroshocking of lake/reservoir sample location areas
- Gill net placement and retrieval within lake/reservoir sampling areas
- Fish tissue collection for analysis of fillet, whole body, and liver tissue from the sampling locations (where catch was permissible for tissue sample collection)
- Collection of fish tissue from a reference pond location (Lindsey Pond) for comparative purposes.

All fish collection locations were collocated with surface water, sediment, benthic macroinvertebrate sample locations.

The following sections describe in detail the techniques used for the fish sampling effort. These activities are in accordance with SOP EE.4, *Sampling of Fishes*. Fish sampling, other related and relevant SOPs, and the OU 3 Work Plan, were followed unless otherwise noted.

Summary of Data Collection Activities - Fish were collected at two distinct time periods (Summer and Fall 1992) from Standley Lake, Great Western Reservoir, and Mower Reservoir. The stream locations (Big Dry Creek, Walnut Creek, and Woman Creek) were only sampled during the Summer because of low flows during the fall. Lindsey Pond was sampled once during the Fall as a reference location. A summary of the capture techniques and the results of catch efforts are provided in the following sections.

A backpack electroshocking unit was used to sample the three stream locations during the Summer months. A 50-foot area of the stream sampling location was traversed with a one-pass electroshocking event. Electroshock unit specifications were dependent upon water quality conditions, and in general, shocking was sustained for approximately 20 minutes within the sampling reach, fish were immediately captured, and retained in live wells for processing. Fish were processed onsite for species identification and enumeration. Those fish that were not identified in the field were preserved in 10 percent buffered formalin for later identification.

A boat-shocker apparatus was used for the reservoir sampling in conjunction with gill nets for the capture of fish. Boat electroshocking activities occurred after nightfall and shoreline areas were electroshocked for 15-minute intervals. Fish were captured and retained in live wells for processing. All fish were identified to species (where possible), measured for total length and weight, and processed for potential fish tissue analyses. Those species that were unidentifiable, were preserved in 10 percent buffered formalin for later identification. Those fish retained for tissue analysis were wrapped in aluminum foil and maintained at refrigerator temperature until further processing was completed (within 24 hours after catch). Fish were then processed to obtain tissue samples. Fish within each trophic class (where possible and applicable) were retained from each station for tissue analysis (herbivores, primary predator, etc.). Whole body, fillet, and liver tissue samples were collected when adequate and appropriate catch was available.

Monofilament gill nets (250 feet in total length, 6 feet in depth) with variable mesh sizes were placed throughout the reservoirs for additional fish sampling. Nets were generally set perpendicular to the shore-line, starting from a designated sampling location and proceeding toward the shore. Nets were bottom set, with the largest mesh size in the deepest portion of the sampling area. Nets were typically set for several hours to a maximum of an overnight set (12 to 16 hours). Fish were retrieved from the net and retained in live wells for processing.

The location of gill nets in relation to sampling locations is depicted in Figures 2-9, 2-10, and 2-11. Fish were processed for tissue sample selection in a similar manner to all other fish collection activities. Fish were identified to species, and measured for total length and weight, and noted for observations of external disease.

Appendix C summarizes capture results for fish from each area and contains relevant field forms for fish sampling.

<u>Analyses Performed</u> - For comparable analysis and correlative statistical purposes, only a subset of the entire set of tissue samples was analyzed for metals and radionuclide content. Final tissues chosen for analysis were selected on the basis of:

- Correlative species and trophic levels between reservoirs and streams
- Tissues appropriate for human health risk assessment
- Relevant tissues for the ecological assessment.

Tissue samples were analyzed for metals and radionuclides. Appendix C summarizes the results of fish tissue sampling and requested analyses.

For QA/QC purposes, tissue duplicate samples were submitted for analyses. To create a duplicate sample, the fish tissue was divided into right and left fillet portions. Each fillet was then submitted as a separate sample.

<u>Refinements to the Work Plan</u> - The activities performed during the two sampling efforts meet the objectives described in Section 2.6. However, refinements to the specified Work Plan details were made

because of a variety of factors. The following briefly describes the refinements to the Work Plan; a comparison of field tasks completed versus the described tasks within the work plan is presented in Table 2-1:

- Fish sampling did not occur within the stream areas during the Fall sampling effort, because of low (or nonexisting) flows.

- Benthic macroinvertebrates could not be collected because of inadequate abundance of organisms.

- Only one sampling location within each stream drainage was sampled for aquatic parameters because most areas were dry because of low (or nonexisting) flows.

- Appropriate background areas were not identified for streams; however, Lindsey Pond (located onsite) was determined as a suitable background lake system for the sampling of fish tissue.

Benthic Macroinvertebrates

Benthic macroinvertebrates are bottom dwelling aquatic organisms retained by a No. 30 mesh (0.595 mm) net or sieve and are large enough to be seen with the naked eye. Examples of these organisms include crayfish, snails, bivalve mollusks, and adult and larval insects. As a group, benthic macroinvertebrates are intimately exposed to both the sediment and the water, are important components of the food web and other ecosystem functions, and respond relatively predictably to both organic and inorganic contamination.

<u>Objectives of the Sampling Program</u> - The purpose of the macroinvertebrate sampling was to characterize the benthic community and evaluate potential ecological effects at potentially-impacted locations. The following outlines the procedures used to collect benthic macroinvertebrate samples in OU 3 reservoirs and streams. These procedures are in accordance with SOP EE.2, Sampling of Benthic Macroinvertebrates, and the OU 3 Work Plan (DOE, 1992a), unless otherwise noted.

<u>Summary of Data Collection Activities</u> Benthic macroinvertebrate sampling was conducted during July 1992 on three OU 3 streams (Woman Creek, Walnut Creek, and Big Dry Creek) and reservoirs (Great Western Reservoir, Mower Reservoir, and Standley Lake) from July 8 through August 5, 1992. Samples were collected at one station per drainage and three to four locations per reservoir. All 10 reservoir locations were sampled during this time period.

Another round of sampling occurred on the reservoirs in September to October 1992. Streams were not sampled because virtually all flow had ceased by September. Figures 2-9, 2-10, and 2-11 depict sampling locations for benthic macroinvertebrates at OU 3 drainages and reservoirs.

Quantitative, semi-quantitative, and qualitative sampling of benthic macroinvertebrates were conducted on each OU 3 stream. Quantitative sampling was conducted using a Surber sampler or a petite Ponar dredge. The Surber sampler, which samples areas of 0.1 m^2, was used to sample in regions where water depth was less than 5 cm. For deeper standing water or very slow current with soft, silty substrates, the petite Ponar dredge was the sampler of choice. Flow conditions and other physical and biological characteristics of the sampling station were documented in the field log.

The Surber sampler was placed flat on the stream bottom such that the opening of the net faces directly into the current. Once in place, large objects such as rocks and sticks are carefully overturned within the sampling area and examined for larger macroinvertebrates. Larger macroinvertebrates were picked from these rocks and placed in the net prior to being discarded. Once the larger stones were removed, the remaining substrate was stirred to a depth of 8 to 12 cm, which dislodges any macroinvertebrates into the current and carries them into the net. The contents of the net were then transferred into a plastic tub where they were examined for additional macroinvertebrates that were still adhering to the substrate. These organisms were picked free of the substrate using tweezers. From the tub, each sample was transferred to a sample container and preserved in a 10 percent formalin solution. This procedure was followed three times per stream over a 25 m section beginning at the lower most stream segment, thus providing triplicate samples.

Semi-quantitative and qualitative samples were also collected on each OU 3 stream. This sampling event involved the use of kick nets and dip nets. The kick-net technique requires two persons, one of whom stands downstream from the net and holds it open into the current. The other person is located upstream from the net and moves upstream disturbing the substrate with his feet, while the person holding the net follows keeping the net within approximately 30 cm from the other's feet.

A petite Ponar dredge was used to collect benthic macroinvertebrates from OU 3 reservoirs. These rope-suspended samplers are triggered with a messenger or closed when they hit bottom, and are suited for sampling mud and fine gravel substrates. Generally, one dredge-full corresponded to one macroinvertebrate sample, however, if moderately hard substrate was encountered, this procedure was repeated until a sample was acquired (in a single grab).

The dredge was brought to the surface and its contents emptied into a temporary holding tub. Ambient water was used to rinse the dredge and dislodge any sediment and macroinvertebrates adhering to the apparatus. The contents of each holding tub were transferred into a rinse bucket with a No. 30 mesh (0.595 mm) screen attached to the bottom. Twisting of the bucket while holding it in the water sifted sediment through the screen. Macroinvertebrates and detritus were trapped against the screen and transferred to a glass pint or quart jar. A 10-percent formalin solution was added to each container for preservation.

Water quality parameters (e.g., pH, dissolved oxygen, and temperature) profoundly affect the distribution and abundance of aquatic organisms. These properties can be altered by human activities, but can vary naturally as well. Therefore, *in situ* water quality measurements were recorded when the samplers were set, and retrieved, and during periodic inspections.

All benthic macroinvertebrate samples were taken in triplicate for comparisons within and between sampling locations. In addition, one duplicate was collected on Walnut Creek and Mower Reservoir, respectively.

Appendix C lists the corresponding sample numbers for each stream and reservoir sampling location.

Analyses Performed - Benthic macroinvertebrate samples at each station were analyzed for genera present, species diversity, total number of organisms by taxa, and the proportion of pollution-tolerant or pollution-sensitive taxa. The data from quantitative samples will be used to determine macroinvertebrate density (standing crop); taxa richness; species diversity; ratio of scraper, filter collector, and shredder functional feeding groups; ratio of pollution-tolerant and pollution-sensitive taxa; and community similarity indices.

Refinements to the Work Plan - In general, sampling of benthic macroinvertebrates was in accordance with the OU 3 Work Plan; however, two refinements were noted. A total of five additional drainage locations were intended to be sampled, however, because of their ephemeral nature, the streams lacked adequate flow to support resident macroinvertebrate populations. Also, numbers of macroinvertebrates were insufficient to provide adequate tissue samples for the intended analyses.

Periphyton

Periphyton refers to a diverse group of aquatic organisms that adhere to underwater surfaces and include algae, protozoans, ratifiers, gastrotrichs, and other taxa of microorganisms. As a group, periphyton are important components of the food web and other ecosystem functions. Biomonitoring efforts at Rocky Flats focus on diatoms, small filamentous algae, and blue-green algae.

Objectives of Sampling Program - The purpose of the periphyton sampling was to evaluate whether water quality in potentially-impacted reservoirs in OU 3 influence colonization of periphyton. The following subsections outline the procedures used to collect periphyton samples in OU 3. These procedures were in accordance with SOP EE.1, Sampling of Periphyton, and the OU 3 Work Plan (DOE, 1992a) except where otherwise noted.

Summary of Data Collection Activities - Quantitative periphyton sampling was conducted in fall 1992 at Great Western Reservoir, Mower Reservoir, and Standley Lake. Quantitative sampling involved placing floating artificial substrate samplers in each of three locations per reservoir on August 18. An extra sampler was collocated in Great Western Reservoir to serve as a QC check, however, upon retrieval, the tray had become detached from the frame and could not be recovered.

Artificial substrate samplers hold eight 1-inch by 3-inch glass slides that serve as the colonizing substrate. These samplers were then anchored to the bottom of each lake at a depth of 4 to 5 feet. Locations were chosen in an attempt to standardize light, temperature, pH, bottom substrate, bank cover, and other general habitat characteristics possible within and between reservoirs. No periphyton sampling occurred in any of the OU 3 streams (Woman Creek, Walnut Creek, and Big Dry Creek) as intended due to their ephemeral nature.

Water quality parameters (e.g., pH, dissolved oxygen, and temperature) were recorded when the samplers were set on August 18 and approximately once per week until they were retrieved on September 11. The following *in situ* water quality parameters were measured:

- pH
- Water temperature
- Specific conductivity
- Hardness
- Alkalinity
- Turbidity
- Dissolved oxygen content

All artificial-substrate samplers from each reservoir were retrieved when the sampling surface of any apparatus was approximately 70 percent colonized. This was determined by visual inspection. Samples were processed immediately following the retrieval of the apparatus, and involved removing the eight glass slides and scraping the surfaces of each slide into a sampling container using a razor blade. Four of the glass slides were scraped into one jar and four slides were scraped into a second jar. A 5-percent formalin solution was added to each container for preservation. Two sample containers represented one sample.

Analyses Performed - The following analyses were then performed on each sample:

- Biomass
- Algal density and
- Taxonomic identification

Appendix C lists the corresponding sample numbers for each location at each reservoir.

Refinements to the Work Plan - Only one refinement to the Work Plan occurred during the periphyton sampling. Initially, qualitative samples from the OU 3 drainages were to be collected. However, this effort was abandoned because of the lack of flow during the Fall 1992 sampling episode. Also, periphyton communities in the drainages were expected to be poorly developed because of the ephemeral nature of the drainages.

2.6.3 Aquatic Toxicity Bioassays

Toxicity testing is a means whereby the potential toxicity of contaminants in water or sediment are assessed directly. Toxicity tests are conducted using sensitive target species in order to supplement toxicity assessments based on dose-response evaluations and comparisons to criteria. Dose-response evaluations and comparisons to criteria address only one contaminant at a time and therefore do not incorporate synergistic or antagonistic effects that may occur when more than one contaminant is present.

Objectives of the Sampling Program

Because dose-response evaluations and comparisons to criteria may not reflect physical or chemical characteristics of surface waters and sediments at OU 3 or the actual bioavailability of the contaminants; the objectives of the toxicity testing were to evaluate the direct toxicity and bioavailability of contaminants in potentially impacted surface waters and sediments on sensitive species.

Summary of Data Collection Activities

Surface water and sediment samples were collected in summer 1992 from Walnut Creek, Woman Creek, Mower Reservoir, and Big Dry Creek. Sampling stations for the toxicity testing were collocated with surface water and sediment sampling locations. An onsite sediment reference station along Rock Creek was also sampled for comparison purposes.

Surface water samples were collected directly from the water column on August 10, 12, and 14 and September 2, 3, and 4, 1992 and sediment grab samples were collected on August 13, 1992. A total of 27 surface water samples and 7 sediment samples were collected. In situ water quality parameters (pH, water temperature, hardness, alkalinity, specific conductance, and dissolved oxygen) were also measured.

Appendix C summarizes the results of aquatic bioassay sampling. Samples were collected in accordance with the OU 3 Work Plan and protocols described in EPA and ASTM guidelines.

Analyses Performed

The surface water and sediment samples were analyzed for toxicity. Chronic toxicity testing was performed using *Ceriodaphnia dubia,* an invertebrate, and *Pimephales promelas* (fathead minnows). Sediment toxicity tests were conducted using amphipod, *Hyallela azteca.* In addition, the sediment samples were analyzed for grain size and total organic carbon because these parameters can influence the concentrations, hence toxicity, of potential contaminants in sediments.

Refinements to the Work Plan

No refinements to the OU 3 Work Plan or SOP were noted. As described in TM No. 1, the number of sampling locations for toxicity testing were reduced because most drainage stations had low or nonexistent flows.

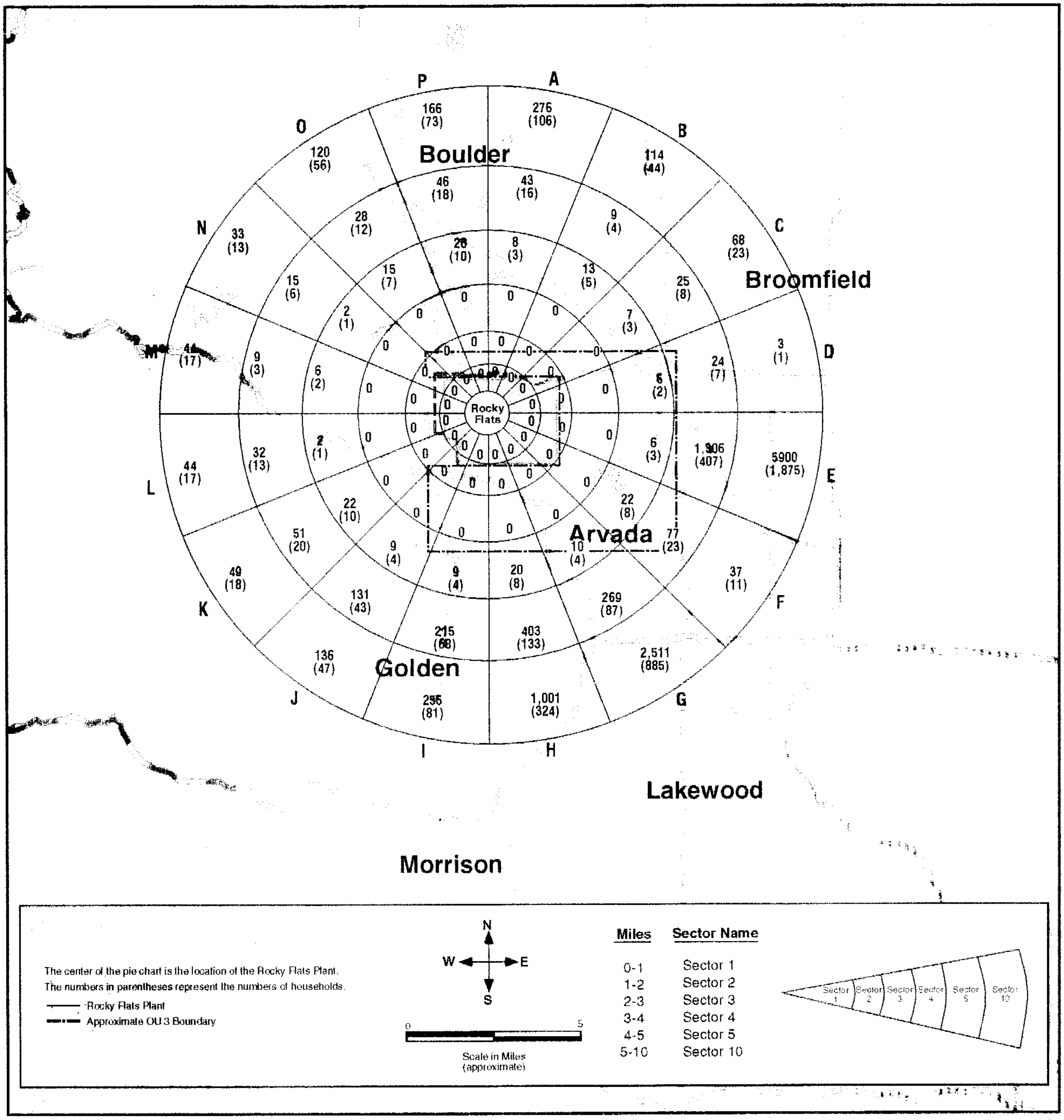

Figure 3-2 1994 Population and (Households) Sectors 1-5

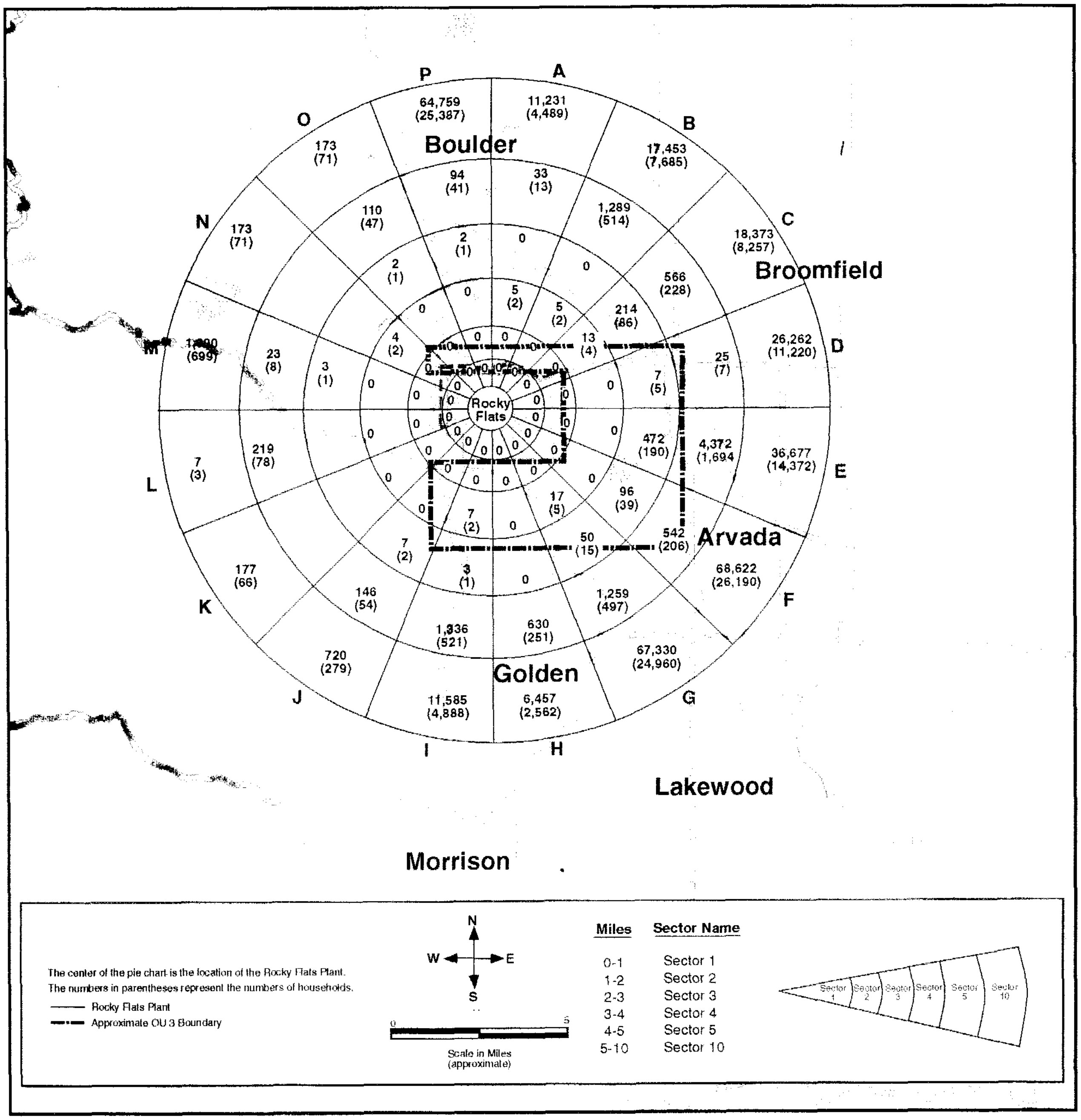

Figure 3-3 2000 Population in the Vicinity of the Rocky Flats Environmental Technology Site Sectors 1-5, 10 (from DOE, 1990).

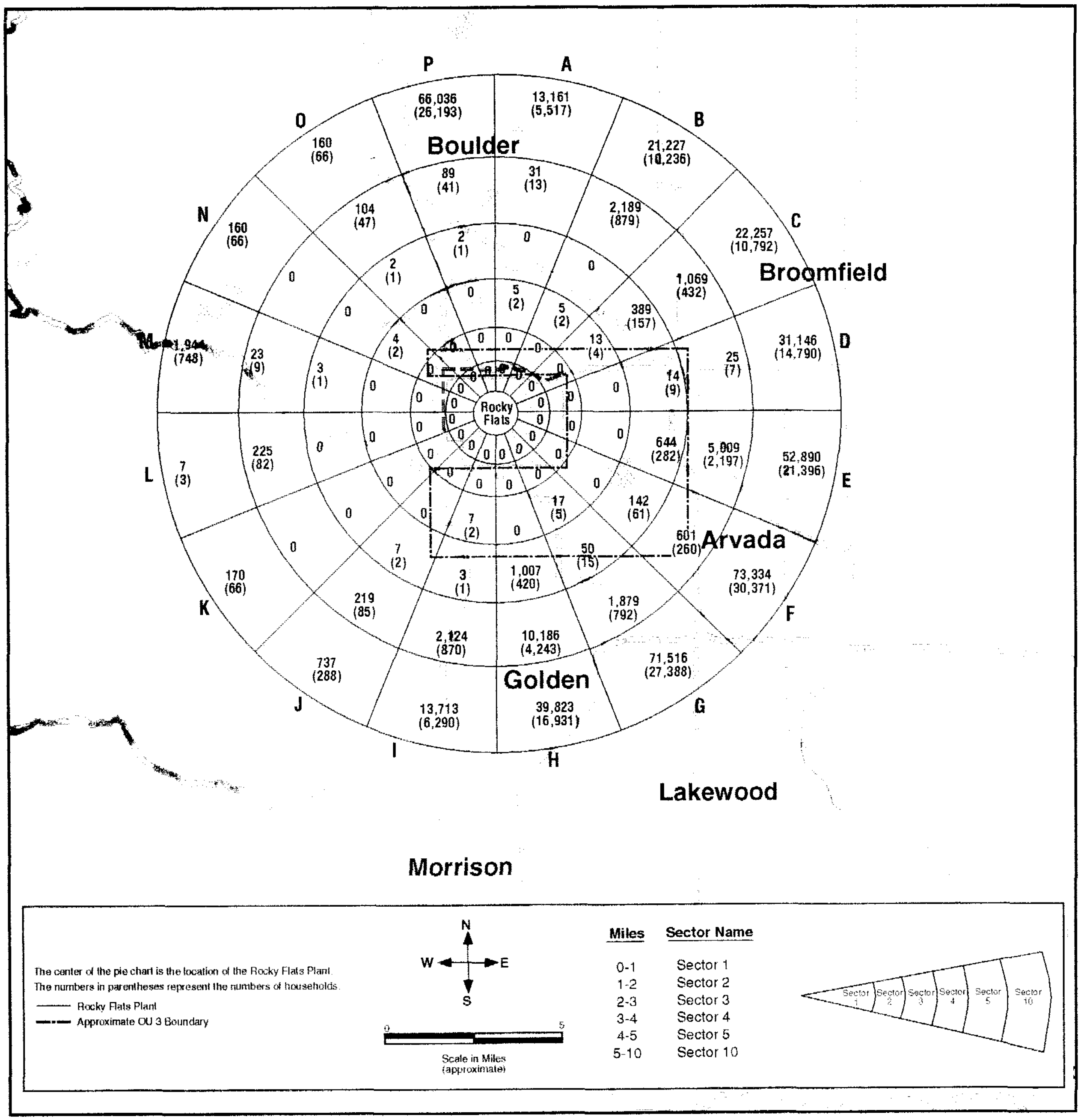

Figure 3-4 2000 Population and (Households) Sectors 1-5, 10 (from DOE, 1990).

3.0 PHYSICAL CHARACTERISTICS OF OU 3

Section 3.0 describes the various physical attributes of OU 3. The OU 3 study area is unique among the Rocky Flats OUs because it is located outside the site boundaries. The following sections describe surface features, demography and land use, meteorology, soils, surface water hydrology, geology, hydrogeology, and ecology for OU 3. Rocky Flats conditions are characterized sufficiently to identify possible pathways and assess the conditions of potential chemical fate and transport at OU 3.

3.1 SURFACE FEATURES

The area west of OU 3 and Rocky Flats is primarily mountainous, sparsely populated, public land (for example, National Forest), whereas OU 3 is primarily a high, arid plain, densely populated to the southeast, and privately owned. OU 3 is located near where the Colorado Piedmont is terminated abruptly by the Front Range section of the southern Rocky Mountains. The Front Range rises to elevations of 12,000 to 14,000 feet (3,660 to 4,270 m) to the west of OU 3 (DOE, 1980).

The Colorado Piedmont represents an old erosional surface along the eastern margin of the Rocky Mountains. It is underlain by gently dipping sedimentary rocks, which are abruptly upturned at the Front Range to form hogback ridges parallel to the mountain front. The piedmont surface is broadly rolling and slopes gently to the east with a topographic relief of several hundred feet (approximately 100 m). This relief is attributed both to resistant bedrock units that locally rise above the landscape and to incised stream drainages. Major stream valleys run predominantly from west to east in the area. Numerous local valleys from minor tributaries also exist (DOE, 1980).

Topographically, the highest point in OU 3 is along Indiana Street, approximately 5,950 feet above mean sea level (AMSL). The lowest point in the vicinity of OU 3 is in the northeast corner, approximately 5,270 feet AMSL (Figure 3-1). The dominant surface drainages are Walnut Creek to the north, and Woman Creek to the south. Both of these dominant drainages flow eastward, supplying water to Great Western Reservoir and Standley Lake, respectively, and eventually converge approximately 5 miles to the east along Big Dry Creek. Flow from these streams finally reaches the South Platte River approximately 25 miles to the east of Rocky Flats. The other dominant surface features include Standley Lake, Great Western Reservoir, and Mower Reservoir.

3.2 DEMOGRAPHY AND LAND USE

The population, economics, and land use of the areas surrounding Rocky Flats are described in a 1989 demographics report by DOE (1991d) for the Rocky Flats vicinity. This report divides general use of areas within 0 to 10 miles (0 to 16 km) of Rocky Flats into residential, commercial, industrial, parks and open spaces, agricultural and vacant, and institutional classifications, and considers current and future land use.

3.2.1 Current and Future Population Projections

A 1994 demographic study shows that approximately 2.2 million people live within a 52-mile radius of Rocky Flats (DOE, 1995). Between 1989 and 1994, the population of the eight-county Denver metropolitan area increased by 73,508.

Most residential use within 5 miles (8 km) of Rocky Flats is located to the east in the highly developed Broomfield subdivision and to the southeast, just below Standley Lake (IHSS 201). Single-family dwellings are located in unincorporated areas immediately east and south of Rocky Flats. Figure 3-2 gives the 1994 population estimates and household numbers within a 10-mile radius of Rocky Flats. The area of Figure 3-2, including Sectors 3 through 5 and pie sections P through J (clockwise), present a general estimate of the population in the OU 3 study area. Sectors 1 and 2 are not considered part of the OU 3 study area because they lie within Site boundaries. Table 3-1 summarizes the sectors and the associated sections (P through J, clockwise) that are pertinent to the OU 3 study area for 1994, 2005, and 2015.

As shown by the 1994 population numbers (from Table 3-1), a direct relationship exists between the distance from Rocky Flats and population growth, with the greatest population growth seen in Sector 5. The population trends exhibited in Table 3-1 correlate with the land uses in these areas.

Figure 3-3 presents the projected population and household numbers for the year 2000 within a 10-mile radius of Rocky Flats. Again, the population estimates for pertinent sectors for the OU 3 study area are given in Table 3-1. An increase is seen in Sector 3 population from 182 in 1994 to 1,957 in 2005. An increase is also seen in Sector 4 population from 2,683 in 1994 to 6,852 in 2005. A greater population growth is exhibited in Sector 5 where in 1994, the population was 10,757 and the projected 2005 population is 17,667.

Projected population and household numbers for the year 2010 are shown in Figure 3-4. Trends in Figure 3-4 reflect those of the 2005 projections (Figure 3-3), in that there is population growth in Sector 4 from 6,852 in 2005 to 10,059 in 2015. The 2015 population projection for Sector 5 shows a significant increase from 10,757 in 1994 to 17,667 in 2005 and finally 23,625 in 2015. This population growth parallels the projected urban development for the area.

3.2.2 Current and Future Land Use

Commercial development is concentrated near the residential developments southeast of Rocky Flats and generally east and south of Standley Lake, and around the Jefferson County Airport approximately 3 miles (4.8 km) northeast of Rocky Flats (Figure 3-5). Industrial land use within 5 miles (8 km) of the plant is limited to quarrying and mining operations. Open-space lands are located northeast of Rocky Flats near the City of Broomfield, and in small parcels adjoining major drainages and small neighborhood parks in the cities of Westminster and Arvada. Standley Lake is surrounded by Standley Lake Park. Irrigated and nonirrigated croplands, producing primarily wheat and barley, are located northeast of Rocky Flats near the cities of Broomfield, Lafayette, and Louisville, north of Rocky Flats

Table 3-1
Summary of Population Sectors in the OU 3 Study Area

Sector	1994 Population	1994 Household No.	2005 Population	2005 Household No.	2015 Population	2015 Household No.
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	182	75	1,957	739	3,318	1,308
4	2,683	868	6,852	2,444	10,059	3,801
5	10,757	3,591	17,667	6,357	23,625	8,904
10	317,828	122,234	355,154	142,948	395,071	167,330

near Louisville and Boulder, and in scattered parcels adjacent to the eastern boundary of the plant. Several horse operations and small hay fields are located south of Rocky Flats. The demographics report characterizes much of the vacant land adjacent to Rocky Flats and the reservoirs as rangeland (DOE, 1991d).

The nearest school to Rocky Flats is Witt Elementary School, which is located approximately 2.7 miles to the east of the buffer zone. The closest hospital is Centennial Peaks Hospital, located approximately 7 miles to the northeast of Rocky Flats. The closest park and recreational area is the Standley Lake area, which is located approximately 5 miles southeast of Rocky Flats. Boating, picnicking, and limited overnight camping are permitted. There are several other small community parks within 10 miles of Rocky Flats. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres for general camping and outdoor recreational use. Other national and state parks are located in the mountains west of Rocky Flats, but all are more than 15 miles away (DOE, 1995).

Future land use in the vicinity of Rocky Flats most likely involves continued suburban expansion, increasing the density of residential, commercial, and perhaps industrial land use in the areas (Figure 3-6). A large area of future residential growth is projected around the perimeter of the Standley Lake Park, where a trend of building to closeout densities is predicted. The primary growth in residential development is projected for the land west of Standley Lake and east of Indiana Street, an area that is currently vacant, undeveloped rangeland (DOE, 1992c).

Significant commercial/industrial growth is projected in the vicinity of the Jefferson County Airport, three miles northeast of Rocky Flats. The City of Westminster has identified the land within its corporate limits that abuts Jefferson County Airport as an "Employment Center." The following developments are encouraged in this area: office parks, shopping centers, office/warehouse complexes, quality restaurants, athletic clubs, research laboratories, and scientific manufacturing facilities (DOE, 1990).

The largest anticipated change in land surface with respect to recreational/open-space use is the addition of more open space to Standley Lake. Figure 3-6 shows more land in the Standley Lake area being dedicated to parks and open space, compared to current land use (Figure 3-5). The Standley Lake Task Force is currently considering the transformation of the Standley Lake area into a state park that would be managed by the Colorado Division of Parks and Outdoor Recreation (DOE, 1992c).

A reduction in open space between Great Western Reservoir and Standley Lake is predicted because of the proposed residential and commercial/industrial development in that area (Broomfield, 1991). However, the open-space area located south of Great Western Reservoir and immediately east of Indiana Street is projected to remain as open space, with less restricted access to the area for recreational/open-space purposes. This land is controlled through zoning limitations and perpetual land use restrictions included in the existing City of Broomfield and City of Westminster deeds of ownership. This open space area includes the approximately 350 acres referred to as the Remedy Lands, (see discussion in Section 1.3).

Currently available land-use and development documents indicate a decline in large-scale parcels of land zoned for agricultural use (CDA, 1993). As shown in the future land use map (Figure 3-6), there are no land areas zoned for agricultural use proposed for the future in the OU 3 study area (DOE, 1990).

3.3 METEOROLOGY AND CLIMATOLOGY

The OU 3 study area has a semiarid climate typical of the Rocky Mountain region, characterized by dry, cool winters and warm summers. Elevation and topography of the nearby Front Range significantly influence climate and meteorological characteristics of OU 3. Annual precipitation is slightly greater than 15 inches (38 cm/year), with more than 80 percent occurring between April and September. Rainfall intensity and duration vary widely. During a 3-year hydrological study of Rocky Flats (1972 to 1975), rainfall intensities varied from less than 0.1 inches/hr (<0.25 cm/hr) to approximately 0.5 inch/hr (1.25 cm/hr) (USGS, 1976). The total number of days per year that precipitation is greater than 0.1 inches is approximately 47. Snowfall averages 85 inches per year (216 cm/year), falling from October through May (DOE, 1980). Soil is generally frozen from approximately the last week in November to the first or second week of March (Doesken, 1993).

Temperatures are moderate; extremely warm and cold weather is usually of short duration. On average, daily summer temperatures range from 55 to 85°F, or 13 to 29°C, whereas winter temperatures range from 20 to 45°F. The growing season, based on the last spring freeze to the first autumn freeze (of temperatures 32°F and colder), is approximately 148 days per year (Doesken, 1993). The low average relative humidity (46 percent) is a result of the orographic effect of the Rocky Mountains.

Winds, though variable, are predominantly north-westerly. Stronger winds occur during the winter months, and the area occasionally experiences gusts in excess of 100 miles per hour. The general annual wind pattern (Figure 3-7) for Rocky Flats illustrates that winds are predominantly from the northwest quadrant approximately 46 percent of the year. Outside of the northwest quadrant, the next largest wind-rose component is due to wind from the west-southwest, which occurs approximately 7.2 percent of the year. The highest velocity winds (greater than 34.5 miles per hour [mph]); greater than 15 meters per second [m/s]); are generally from the west-northwest and west. Topographic conditions specific to OU 3 may cause local variations in wind direction; however, the annual averages are not expected to differ significantly from those for Rocky Flats.

3.4 SOILS

The surface soils at OU 3 are generally deep, well-drained loams, ranging from gravelly to cobbly clay loams. Soils in the area exhibit similar characteristics, including slow permeability and high shrink-swell potentials. Erosion may be a severe hazard along steep slopes, especially when coupled with rapid runoff. Generally, soils within OU 3 are undisturbed, although many soil sample plots were found heavily grazed or damaged by prairie dogs. Table 3-2 summarizes the soil plot characteristics.

The Standley-Nunn series is the most dominant soil series within OU 3. Heavy deposits exist south of the Boulder/Jefferson county line and in the areas surrounding Standley Lake. Normally found on relatively flat ridges and high terraces, this calcareous, gravelly clay loam has a weak fine granular structure. Its surface layer is mildly alkaline and approximately 8-inches-thick.

Most of the soil series in OU 3 may be classified within the Argiustoll group. Argiustolls are generally loamy, deep, well-drained soils found along hill slopes and ridge crests. Soils from the Argiustoll group are well-suited for grazing, because these clay-rich, dry mollisols support plant growth in arid climates (USDA, 1980).

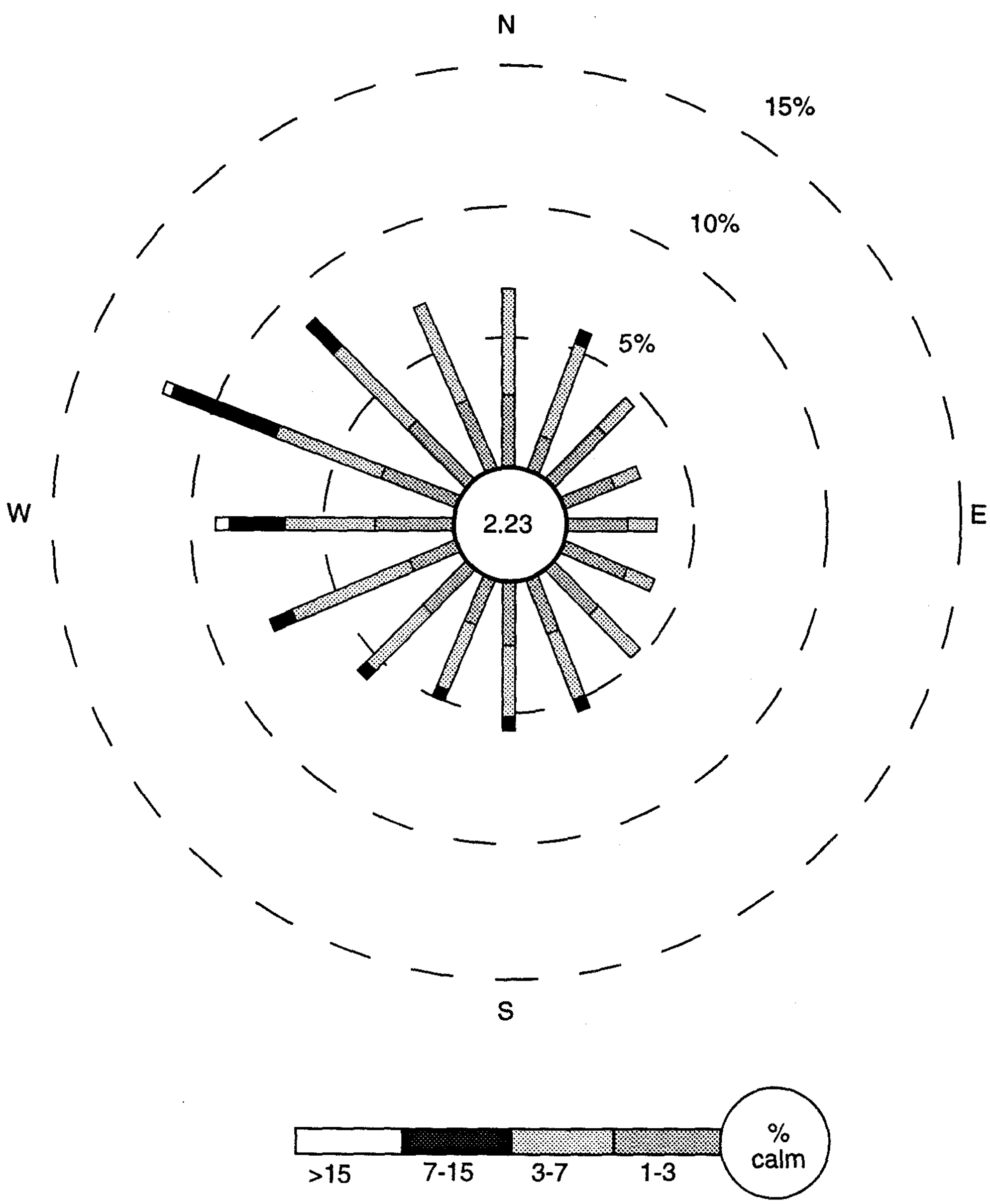

Figure 3-7 RFP 1991
Wind Rose 24-Hour

Table 3-2
Soil Plot Characteristics OU 3

Plot No.	Soil Classification	Sample Date	Field Observations
PT12592	Samsil-Shingle	02 June 93	Sloping south with small drainage running W-E in southern fifth of plot.
PT12692	Nunn	02 June 93	Good ground cover, relatively flat and undisturbed. Abandoned cattle pond and concrete structures exist at western portion of plot.
PT12792	Denver-Kutch	27 January 93	No obstruction, very rocky, slopes steeply to SW.
PT12892	Denver-Kutch/ Denver-Kutch-Midway	8 April 93	Rocky, gently sloping with drainage running E-W through middle of plot. Used as cow pasture.
PT12992	Standley-Nunn/ Denver-Kutch-Midway	8 April 93	Very rocky, very hilly, used as cow pasture.
PT13092	Valmont	28 May 93	Flat with good grass cover.
PT13192	Denver-Kutch-Midway	23 February 93	Short grasses, grazed by cows, no obstructions. Dry soil, cobble on south portion.
PT13292	Denver-Kutch-Midway	23 February 93	Relatively flat, slight slope to north, no obstructions, moist ground.
PT13392	Haverson/Denver-Kutch	5 February 93	Slopes to north, relatively undisturbed. Even surface, generally covered with short grasses. Creek borders north boundary of plot. No obstructions, lightly grazed, wet soil.
PT13492	Samsil-Shingle	24 February 93	No descriptors.
PT13592	Denver-Kutch/ Standley-Nunn	9 February 93	No descriptors.
PT13792	Haverson/Denver-Kutch-Midway	1 February 93	Somewhat flat rising toward southern border. Numerous creeks/ditches (E-W). Relatively undisturbed with high grasses and trees.
PT13992	Leyden-Primen-Standley	23 July 92	Bounded by Highway 128 on north, road on south, Indiana Street on west. Barbed wire fence on south portion running E-W, powerline runs SE-NW.
PT14092	Haverson/Denver	25 June 92	Relatively undisturbed, high voltage power. Land and road running N-S.

Table 3-2 (continued)

Plot No.	Soil Classification	Sample Date	Field Observations
PT14192	Leyden-Primen-Standley/ Standley-Nunn/Denver	1 July 92	No obstructions fence runs E-W along northern end of plot. Ridge crest divides plot along E-W.
PT14292	Denver-Kutch	30 June 92	Creek running E-W in southern portion of plot.
PT14392	Standley-Nunn	6 July 92	Plot is fenced, no obstructions.
PT14492	Standley-Nunn	2 April 93	Uncut hayfield, flat.
PT14592	Nunn/Haverson/ Denver-Kutch	27 May 93	Horse/cow pasture, livestock in plot, drainage runs diagonal (NE-SW).
PT14692	Lebsack/Denver-Kutch	28 May 93	Moist soi, high in organic content, good grass cover.
PT14792	Nunn/Lebsack	2 February 93	Relatively flat and undisturbed. Dirt path parallels north boundary. High grasses. West boundary parallels dam. Swamp conditions along small creek paralleling south border.
PT14892	Samsil-Shingle/Kutch	26 February 93	Flat with short grasses.
PT14992	Denver-Kutch/ Standley-Nunn	25 January 93	Slopes to south.
PT15092	Leyden-Primen-Standley/ Standley-Nunn	25 January 93	Very moist soil conditions. No obstructions, plot slopes moderately steeply to south, ditch along north border.
PT15192	Standley-Nunn	2 July 92	Pipeline mount in SW corner. DIrt roads cutting across plot.
PT15292	Nunn	26 January 93	No obstructions, relatively flat.
PT15392	Nunn	6 July 92	Swale running N-S, road, hillside in NE corner.
PT15492	Heldt/Nunn	9 July 92	Tall grass, drainage running SW-NE into Standley Lake. Ditch cornering SW. Gate parallel to west border and dirt road parallel to south border, both outside of plot.
PT15592	Englewood/Standley-Nunn	8 February 93	Soil high in organic content. Plot relatively flat, grazed by cows.
PT15692	Denver-Kutch Midway/Denver	22 February 93	Pasture for cows and horses, short grass. Soil moderately high in organic content. No major obstructions.

Table 3-2 (continued)

Plot No.	Soil Classification	Sample Date	Field Observations
PT15792	Samsil-Shingle	24 February 93	Moderate grass cover, some prairie dogs live on site. No major obstructions. Drainage running N-S along western third of plot.
PT15892	Leyden-Primen-Standley/Denver	28 July 92	No obstructions, land disturbed.
PT15992	Leyden-Primen-Standley/ Standley-Nunn	30 July 92	No obstructions, beaten road in SW corner.
PT16092	Nunn-Urban	31 July 92	Creek running parallel to north boundary.
PT16192	Standley-Nunn	26 January 93	No obstructions, relatively flat.
PT16292	Nunn/Pits	8 July 92	Dirt roads running through plot. Steep hill and gravel pit in NE corner.
PT16392	Heldt/Midway/ Denver-Kutch-Midway	9 July 92	Ditch in NW corner of plot. Sloping hill in S-SW region.
PT16492	Nunn-Urban/Nunn-Urban	9 February 92	Canal along southern border. Rectangular plot, used for alfalfa. Soil high in organics.
PT16592	Kutch/Samsil-Shingle	5 April 93	Drainage running E-W through center of plot. Good grass cover, very moist soil. Slightly sloping.
PT16692	Samsil-Shingle	2 April 93	Good vegetation cover. Road cutting diagonally SE-NW. Drainage running N-S.
PT16792	Leyden-Primen-Standley/ Manzanola-Renohill -Stoneham	29 July 92	Disturbed area, Airport water tanks in NE corner. Fence runs along northern border.
PT16992	Standley-Nunn/Pits	26 June 92	Hilly, rocky, hard soil. Road runs NW-SE.
PT17092	Heldt/Midway	10 July 92	Dirt roads section plot.
PT17192	Samsil-Shingle/Nunn	5 April 93	Flat with moderate grass cover. Sloping gently to the east. Road parallels northern boundary.
PT17292	Englewood/Ulm	7 April 93	Relatively flat, high disturbed. Little or no ground cover. Drainage through west side.
PT17392	Standley-Nunn/Leyden Primen-Standley	3 August 92	Plot located near runway.
PT17492	Ulm/Nunn	4 June 93	Relatively flat and undisturbed. Good grass cover.

Table 3-2 (continued)

Plot No.	Soil Classification	Sample Date	Field Observations
PT17692	Nunn/Manzanola/Arvada	22 July 92	Fence along east boundary, raised mount on west side.
PT17792	Manzanola	22 July 92	Lake on west side, volleyball court in SW corner.
PT17992	Ulm-Urban	28 January 93	Hill grazed by horses.
PT18592	Denver-Kutch-Midway/ Denver-Kutch	2 July 92	Hill runs NW-SW through center of plot.
PT18692	Standley-Nunn	23 July 92	Plot surrounded on north and west side by barbed wire fence. Slight dirt mound in SW corner.
PT18792	Leyden-Primen-Standley	22 January 93	Drainage gully in SW corner.
PT18892	Manzanola-Renohill-Stoneham/Leyden-Primen-Standley/ Standley-Nunn	6 April 93	Slightly hilly, cobble stream, poor vegetation.
PT18992	Ulm	6 April 93	Slopes gently to the east. Poor to moderately poor vegetation. Drainage runs NW/SE.
PT19092	Manzanola/Ulm-Urban	8 February 93	Flat land surface at creek level. No major obstructions. Plot is moderately covered with short vegetation. Prairie dogs on site.
PT19192	Denver-Kutch/Denver/ Willowman-Leyden/ Standley-Nunn	1 April 93	Good grass cover, cobbles. Undulating terrain.
PT19292	Haverson/Standley-Nunn	1 April 93	Moderate vegetation cover, flat. Prairie dogs on site.
PT19392	Platner	7 April 93	Flat, relatively undisturbed. DIrt road runs east-west. Moderately good vegetation.
PT19492	Standley-Nunn	24 May 93	No descriptors.
PT19592	Denver-Kutch/ Denver-Kutch	26 May 93	Slopes to the north. Good ground cover. Road cuts through middle of plot.
PT19692	Standley-Nunn/ Denver-Kutch	27 May 93	Plot slopes to north. Moderate density of prairie dog burrows, thick vegetation cover, cobble stream.

Table 3-2 (continued)

Notes:

Soil Classification	Slope %
Kutch clay loam	3-9
Samsil-Shingle complex	5-25
Valmont cobbly clay loam	5-25
Arvada clay loam	0-2
Denver clay loam	2-9
Denver-Kutch clay loams	5-15
Denver-Kutch-Midway clay loams	9-25
Englewood clay loam	0-2
Haverson loam	0-3
Heldt clay	9-15
Lesback clay loam, saline	0-2
Leyden-Primen-Standley cobbly clay loams	15-50
Manzanola clay loam	5-25
Manzanola-Renohill-Stoneham complex	9-15
Midway clay loam	9-30
Nunn clay loam	0-5
Nunn-Urban land complex	0-5
Pits, clayey	N/A
Platner loam	3-5
Standley-Nunn gravelly clay loams	0-5
Ulm clay loam	5-9
Ulm-Urban land complex	5-9
Willowman-Leyden cobbly loams	9-30

Source: USDA, 1980. Soil Survey of Golden, Colorado

3.5 SURFACE WATER HYDROLOGY

Five drainage basins are located within the OU 3 study area as shown on Figure 3-8 (DOE, 1992b). These basins are, from south to north, Upper Big Dry Creek, Woman Creek, Great Western Reservoir basin, Walnut Creek (diverted around Great Western Reservoir), and Rock Creek. Woman Creek and Walnut Creek are tributaries of Big Dry Creek. Major impoundments within OU 3 include Standley Lake, Great Western Reservoir, and Mower Reservoir.

The Big Dry Creek Basin is 8.1 square miles in area and includes two primary drainages. These drainages are Upper Big Dry Creek (North) and Upper Big Dry Creek (South). Most of the Big Dry Creek Basin is located south of the site buffer zone (about 9 percent of the watershed lies within the buffer zone).

The Woman Creek Basin is 5.1 miles in area and flows through the site buffer zone directly south of the main plant area. The two primary drainageways in the Woman Creek Basin include Woman Creek on the north and a drainageway on the south generally referred to as Smart Ditch No. 1. The northern drainage of Woman Creek is 2.3 square miles in area and located generally east of the site buffer zone (about 18 percent of the watershed lies within the buffer zone). This northern drainage contains a series of gently sloping swales; no well-defined stream channels are present.

The Colorado Water Quality Control Commission (WQCC) has established beneficial uses for Big Dry Creek, Woman Creek, Walnut Creek, Standley Lake, and Great Western Reservoir. Big Dry Creek (WQCC Segment 1) is classified as a Class 2 recreational stream (suitable for recreational uses that do not include primary contact with the body). For aquatic life, Big Dry Creek has a Class 2 warm-water classification (not capable of sustaining a wide variety of warm-water biota, including sensitive species). It is not classified as a water supply, but is classified for agricultural use.

The Walnut Creek Basin receives most of the stormwater runoff from Rocky Flats. Walnut Creek drains southeast beyond Great Western Reservoir, entering Big Dry Creek about 3 miles downstream of Standley Lake. The Big Dry Creek Basin, to the east of Standley Lake, is an urban watershed that receives runoff from the area upstream of Standley Lake and Great Western Reservoir and conveys it to the South Platte River near Fort Lupton.

Rock Creek flows through the northwestern corner of the site buffer zone and does not receive runoff from the industrial area of Rocky Flats. It has been maintained in an undisturbed condition since the site boundaries were established in 1957. Rock Creek flows to Coal Creek, which is a tributary to Boulder Creek. Rock Creek was sampled during the background sampling program (See Appendix C).

3.5.1 Drainages and Ditches

Woman and Walnut Creek drainages have a higher probability of impact from Rocky Flats activities than other drainages in OU 3. The Woman Creek basin flows through the Rocky Flats buffer zone and the Walnut Creek basin receives stormwater runoff from the Rocky Flats industrial area.

Woman Creek

The Woman Creek watershed drains the approximately 2,827 acres (1,144 hectares) south of the industrial area and the east-west access road. The channel length of Woman Creek on Rocky Flats is about 3.1 miles (5 km). Within the site boundary, the Woman Creek drainage contains two C-series holding ponds; Pond C-1 (maximum volume 1.7 million gallons [MG]) and Pond C-2 (maximum volume 22.6 MG), which are located south and east of the main production area, respectively (Figure 3-9). The flow that Pond C-1 receives from Woman Creek is diverted around Pond C-2 and back into the Woman Creek channel downstream of Pond C-2. Pond C-2 receives surface runoff from the South Interceptor Ditch, which collects surface runoff from the southern portion of Rocky Flats main production area (Rockwell, 1988a). The South Interceptor Ditch runs along the south (downgradient) side of the main production area, between the controlled area and Woman Creek (Figure 3-9). Pond C-2 water formerly was discharged into Woman Creek, in accordance with the NPDES permit for Rocky Flats, however, more recently, water has been pumped from Pond C-2 into a treatment facility, then through an above-ground pipeline to the Broomfield Diversion Ditch, where it was discharged in accordance with applicable regulations and by agreement with the City of Broomfield.

Woman Creek (WQCC Segment 4) is classified as a Class 2 recreational stream and a Class 2 warm-water aquatic system. Woman Creek is also classified as a water supply and agricultural water supply.

Walnut Creek

An east-west trending topographic divide separates the Woman Creek and Walnut Creek watersheds. Walnut Creek watershed drains approximately 2,170 acres (879 ha) in the northeastern and central portions of Rocky Flats. The channel length of Walnut Creek is about 4.3 miles (7 km). This length of Walnut Creek consists of two forks, Walnut Creek and South Walnut Creek, which drain the northeastern and central portions of Rocky Flats respectively. The A-series detention ponds, A-1, A-2, A-3, and A-4, have maximum volumes of 1.40, 6.00, 12.37 and 32.50 million gallons (MG), respectively, in the Walnut Creek channel (EG&G, 1994c). The nondischarging Landfill Pond (maximum volume 7.2 MG), located just north of the industrial area, is at the head of an unnamed tributary entering Walnut Creek.

The B-series detention ponds, B-1, B-2, B-3, B-4, and B-5, have maximum volumes of 0.50, 1.50, 0.57, 0.18, and 24.19 MG, respectively, in the South Walnut Creek channel (EG&G, 1994c). The Sewage Treatment plant, within the industrial area, drains into Pond A-4. Downstream from the A- and B-series detention ponds, another small impoundment is located at the eastern boundary of the site. Immediately beyond the east buffer-zone fence, the streamflow from Walnut Creek is diverted around Great Western Reservoir via the Broomfield Diversion Ditch. Walnut Creek flow from Rocky Flats is treated and diverted south around Great Western Reservoir into the drainage below the reservoir outlet, where it combines with outflow from the reservoir. The Broomfield Diversion Ditch prevents surface water from Rocky Flats from reaching Great Western Reservoir.

Walnut Creek (WQCC Segments 4 and 5) is classified for Class 2 recreational and Class 2 warm-water aquatic uses. Walnut Creek is also classified as a water supply and agricultural supply.

Other Drainages and Diversions

Rocky Flats is crossed by several of the irrigation ditches in the regional network of drainage canals. Smart Ditch begins at Rocky Flats Lake and was constructed along the site's southern border. Two irrigation detention ponds located in the southeast corner of the buffer zone are part of the Smart Ditch system. These ponds are referred to as D-1 (normally filled) and D-2 (usually dry). Also, McKay Ditch, which carries water across the central to north-central portion of the buffer zone, flows into Walnut Creek.

3.5.2 Reservoirs

Great Western Reservoir (IHSS 200)

Great Western Reservoir is located 1.5 miles east of the site's eastern boundary (see Section 1.3). Great Western Reservoir is classified as a Class 1 recreational use and Class 1 warm-water aquatic reservoir. Presently, Great Western Reservoir has a potable water supply. However, the City of Broomfield plans to abandon Great Western Reservoir as a drinking water supply, as part of the implementation of a DOE grant project. The Class 1 recreation means the surface waters are suitable for primary contact with the body and ingestion of small quantities of water is likely. Even though Great Western Reservoir is classified as a Class 1 recreational resource, access to the reservoir is restricted and there are no current recreational uses permitted. The Class 1 warm-water aquatic means the waters are currently or could be capable of sustaining a wide variety of warm-water biota, including sensitive species.

Standley Lake (IHSS 201)

Historical data for Standley Lake indicate the lake is at its lowest capacity during January, February, and March, and at its highest capacity during June, July, and August. The lowest capacity in Standley Lake was approximately 29,900 acre-feet, in January 1989, and its highest capacity was approximately 43,300 acre-feet, in June 1988 through 1991 (DOE, 1992d).

Standley Lake (WQCC Segment 2) is classified as a Class 1 recreational use and Class 1 warm water aquatic lake. Standley Lake is also classified as both a potable water supply and suitable for agricultural use. Section 1.3 contains more details on Standley Lake.

Mower Reservoir (IHSS 202)

Little documentation exists for Mower Reservoir, a small, privately owned impoundment located approximately 1.5 miles southeast of Rocky Flats (and approximately 1,500 feet from the eastern site buffer-zone boundary. The reservoir is fed by Woman Creek via Mower Ditch, an irrigation ditch that originates within the site boundary. The water rights to Mower Reservoir, an agricultural resource, are privately owned by a farmer in the area and the land area around the reservoir is owned by the City of Westminster. Mower Reservoir is used for irrigation of pasture land and water for livestock. Mower Reservoir covers approximately 9 acres (3.6 ha) of surface area and is roughly 5 to 10 feet at its deepest point (DOE, 1992a).

Mower Reservoir has no WQCC classification. Section 1.3 contains more specific details on the reservoir.

3.5.3 Water Quality Characterization

As described in Section 2.3, water quality characteristics were gathered at each surface water and sediment sampling location. The results of these measurements are provided in Table 3-3. Trends observed for the field parameters indicate that the stream and reservoir locations all have characteristics common to freshwater environments with the exception of pH measurements for Mower Reservoir; pH ranged from 7.76 to 8.26 in Great Western Reservoir, 6.85 to 8.83 in Standley Lake, and 9.80 to 10.40 in Mower Reservoir. Stratification influences were observed in Standley Lake. The pH characteristics of Mower Reservoir and the stratification of Standley Lake are discussed in the following subsections.

Mower Reservoir pH

Mower Reservoir was characterized by an abundance of submerged and emergent vegetation, with abundant aquatic life (both fish and invertebrates). The maximum observed depth within the reservoir was 6 feet. The photosynthesis period appeared to influence bicarbonate concentrations by controlling the concentration of dissolved gases (CO_2, O_2) in the lake. In response to increased CO_2 concentrations during the photosynthesis period, a prevalent, basic pH occurred. The diurnal (daily) effects of the photosynthesis period were investigated by conducting measurements of pH and temperature within the lake from early morning hours (4:30 a.m.) until after dawn (6:00 a.m.). During the photosynthetic period (i.e., daytime), plants produce oxygen and consume carbon dioxide. During the nonphotosynthetic period (i.e., nighttime) respiration and decay consume oxygen and produce carbon dioxide. This alternating cycle results in a well defined diurnal fluctuation of pH. An observed trend was that an increasingly basic pH occurred with increasing sunlight; at 4:30 a.m., pH was 8.75; whereas, at 6:00 a.m., pH was 9:57.

Stratification

Stratification is the separation of water layers in response to temperature effects and water density. It is a common occurrence for lake systems in which there are severe temperature changes. During spring and summer, a less dense, warmer layer occurs at the surface (called the hypolimnion), which is separated by a thermocline from the more dense cooler bottom layer (called the epilimnion). Stratification can occur during both spring/summer and fall time periods in response to ambient temperature changes.

The differing temperature regimes within each layer can affect water quality characteristics such as the concentration of dissolved oxygen. During a stratified condition, dissolved oxygen levels can significantly decrease with depth. With the occurrence of the phased separation of layers, mixing and aeration of the deeper water layers diminishes. Also, turbid environments can decrease or preclude for photosynthetic activities at increasing depths. As a result of diminished photosynthetic activity, the natural supply of oxygen subsides. In addition, microbial decay of bottom material uses available oxygen for the degradation process, and can, therefore, contribute to anoxic conditions in deeper waters. These anoxic conditions will also influence the habitat suitability of the area for use by aquatic life. Stratification processes that cause the anoxic conditions at depth also influence redox potential and subsequent contaminant bioavailability. Measurements of temperature and dissolved oxygen were collected on a depth continuum within Great Western Reservoir (IHSS 200) and Standley Lake (IHSS 201), in order to determine if stratification exists. In the instance where stratification occurred, a distinct depth-specific sample was collected at each layer (one sample each at the hypolimnion, thermocline, and epilimnion).

Stratification was observed at one location (SW03592) within Standley Lake in late July, possibly in response to a prolonged period of hot weather. Samples were collected and depth-specific water quality information was gathered. Analytical results for the stratified samples are discussed in Section 4. No stratification was observed during the sampling of Great Western Reservoir. The shallowness of Mower Reservoir precluded stratification; the maximum observed depth within Mower was 6 feet, and the water clarity was typically high (minimal turbidity). The water quality characteristics gathered at each sampling location are presented by depth and by reservoir in Table 3-3.

Table 3-3
Water Quality
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Sample Location	Date Collected	Depth (ft)	Water Temperature (deg. C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Turbidity (NTU	Hardness (mg/L)	Alkalinity (mg/L)
Walnut Creek									
BIO15192	7/10/92	0	18	7.9	7.92	105	15.6	52	30
BIO15192	7/8/92	0	16	6.2	6.27	20	16.3	70	63
Woman Creek									
BIO15292	7/13/92	0	17	7.3	7.46	154	11.4	50	43
Big Dry Creek									
BIO15392	7/9/92	0	14	5.4	5.99	60	11.4	108.5	
Great Western Reservoir									
BIO17192	9/30/92	7.87	17.6	10.75	8.2	186		72	55
BIO17192	7/11/92	0	22	8.1	7.76	201	24.4	64	54
BIO17192	9/29/92	7.87	16	7.53	8.1	186		70	53
BIO17192	7/11/92	15	20	6.3					
BIO17192	7/11/92	10	21	6.4					
BIO17292	7/11/92	5	21	6.5					
BIO17292	7/11/92	20	20	6					
BIO17292	7/11/92	15	20	6					
BIO17292	7/11/92	0	22	7.5	7.9	208	24.6	73	46
BIO17292	7/11/92	10	20	6.2					
BIO17292	9/29/92	18.04	16.2	4.92	8	184		67	51
BIO17292	7/11/92	24	20	6					
BIO17292	9/30/92	18.04	17.5	8.89	8.11	186		70	51
BIO17392	9/30/92	34.12	16.5	12.12	8.12	186		70	59
BIO17392	7/11/92	10	20	6.5					
BIO17392	7/11/92	40	20	5.8					
BIO17392	7/11/92	20	20	6.2					
BIO17392	9/29/92	34.12	16	3.65	7.96	184		66	42
BIO17392	7/11/92	0	21	6.8	8.26	200	26.4	76	43
BIO17392	7/11/92	30	20	6					
Mower Reservoir									
BIO17692	7/17/92	5	19	4.4					
BIO17692	10/6/92	4.98	13.6		9.96	262	1.3	87	83
BIO17692	7/17/92	2.5	19	8.8					
BIO17692	10/7/92	3.93	11.1		10.13	272	0.8	77	63
BIO17692	7/17/92	0	22	8.4	10.1	233	1.5	88	93
BIO17792	7/17/92	5	19	4					
BIO17792	7/17/92	0	21	9.2	10.4	240	1.4	77	90
BIO17792	7/17/92	2.5	19	6.3					
BIO17792	10/6/92	4.49	13.6		9.98	272	1.12	74	96
BIO17792	10/7/92	4.59	11.1		10.25	274	3.2	80	68
BIO17892	7/17/92	3	18	7					
BIO17892	7/17/92	6	18	3.8					
BIO17892	10/6/92	4.49	14		10.25	274	1.4	90	86
BIO17892	7/17/92	0	19	8	9.8	245	2.3	72	87

Table 3-3 (continued)

Sample Location	Date Collected	Depth (ft)	Water Temperature (deg. C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Turbidity (NTU	Hardness (mg/L)	Alkalinity (mg/L)
Standley Lake									
SW03192	7/27/92	8	22	8					
SW03192	7/27/92	0	24	8.2	7.9	261	1.64	71	46
SW03192	7/27/92	16	21	7.8					
SW03292	7/30/92	0	22	7	8.83	246	2.4	89	69
SW03292	7/29/92	20	21	6.4					
SW03292	7/29/92	10	21	6.8					
SW03392	7/27/92	0	21	7.8	6.85	260	1.87	71	46
SW03392	7/27/92	9	21	7.6					
SW03392	7/27/92	18	21	7.6					
SW03492	7/28/92	20	20	8					
SW03492	7/28/92	0	22	8.8	8.02	207	1.7	87	60
SW03492	7/28/92	10	21	8.4					
SW03592	7/27/92	39	18	2.4					
SW03592	7/28/92	50	15	1.8					
SW03592	7/27/92	37	18	2.4					
SW03592	7/28/92	55	15	1.9					
SW03592	7/27/92	41	17	2.2					
SW03592	7/28/92	60	15	1.9					
SW03592	7/27/92	45	16	1.8					
SW03592	7/28/92	65	14	1.8					
SW03592	7/27/92	50	16	1.8					
SW03592	7/28/92	70	14	1.6					
SW03592	7/27/92	31	19	4.4					
SW03592	7/28/92	75	14	1.6					
SW03592	7/28/92	10	21	7.9					
SW03592	7/27/92	29	20	5.6					
SW03592	7/28/92	20	20.5	7					
SW03592	7/27/92	27	20	6.2					
SW03592	7/28/92	30	18	3.6					
SW03592	7/27/92	25	21	6.6					
SW03592	7/28/92	40	16.5	1.9					
SW03592	7/27/92	82	13	0.2					
SW03592	7/27/92	35	18	3					
SW03592	7/27/92	75	14	0.6					
SW03592	7/27/92	47	16	1.8					
SW03592	7/27/92	50	16	1.8					
SW03592	7/28/92	5	21	8					
SW03592	7/27/92	25	20	7					
SW03592	7/28/92	25	19	5.8					
SW03592	7/27/92	0	22	8					
SW03592	7/28/92	45	16	1.9					
SW03592	7/29/92	0	22	8.2	8.44	257	1.5	100	50
SW03592	7/27/92	33	19	3.8					
SW03592	7/29/92	30	18	3.6	7.78	230	3.5	101	51

Table 3-3 (continued)

Sample Location	Date Collected	Depth (ft)	Water Temperature (deg. C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Turbidity (NTU	Hardness (mg/L)	Alkalinity (mg/L)
Standley Lake (continued)									
SW03592	7/28/92	35	17	2					
SW03592	7/28/92	15	21	7.9					
SW03592	7/27/92	43	17	2					
SW03592		75	13.9	1.8	8.45	395	9.4	128	60
SW03592	8/5/92	79	21.8	7.6	7.26	196	0.85	148	46
Reference									
SEDREF92	8/13/92	0.16	15	6.2	5.8	297	5.06	134	97
Great Western Reservoir									
SW02192	7/14/92	5	20	6.5					
SW02192	7/15/92	0	21	6.8	7.45	245	24.3	61	58
SW02192	7/15/92	15	19	6.2					
SW02192	7/15/92	10	20	6.4					
SW02292	7/15/92	0	22	8	7.96	213	24.5	63	52
SW02292	7/15/92	10	20	7.8					
SW02292	7/15/92	20	19	7.6					
SW02392	7/16/92	40	17	6.6					
SW02392	7/16/92	30	18	6.8					
SW02392	7/16/92	20	18	6.8					
SW02392	7/16/92	0	20	7.2	7.45	195	24.5	74	34
SW02392	7/16/92	10	19	7					
SW02492	7/16/92	9	18	6.6					
SW02492	7/16/92	5	19	6.8					
SW02492	7/16/92	0	19	6.4	7.35	196	25.1	62	36
SW02592	7/16/92	0	19	6.6	7.2	212	27.1	71	52
SW02592	7/16/92	10	17	6.2					
SW02592	7/16/92	30	17	6.2					
SW02592	7/16/92	20	17	6.2					
SW02592	7/16/92	40	17	6.2					
Mower Reservoir									
SW02692	7/20/92	2.5	21	8.8					
SW02692	7/20/92	5	19	1					
SW02692	7/20/92	0	23	9.4	11.17	297	1.6	52	
SW02792	7/20/92	2.5	21	9.2					
SW02792	7/20/92	0	23	8	10.95	290	2.03		
SW02792	7/20/92	5	19	1					
SW02892	7/20/92	0	22	9	10.7	282	1.8	51	
SW02892	7/20/92	4	20	1.8					
SW02892	7/20/92	2	21	9.4					
SW02992	7/20/92	2.5	20	9					
SW02992	7/20/92	5	19	7.8					
SW02992	7/20/92	0	20	9.2	10.7	281	2.1	58	
SW03092	7/21/92	0	20.5	8.2	10.7	255	1.7	64	
SED01392	9/2/92	0.16	16	8.8	9.14	280	0.76	73	92
SED01392	9/3/92	0.16	20.7	13.4	9.78	318	1.3	71	70

Table 3-3 (continued)

Sample Location	Date Collected	Depth (ft)	Water Temperature (deg. C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Turbidity (NTU	Hardness (mg/L)	Alkalinity (mg/L)
Mower Reservoir (continued)									
SED01392	8/10/92		20	8	9.13	198	0.6	88	75
SED01392	8/12/92	0.16	19	7.2	10.2	279	0.64	68	73
SED01392	8/31/92	5	17	8	9.72	275	1.13	71	63
SED01392	8/10/92		22	8.6	9.89	211	0.6	68	75
SED01392	8/10/92	0.16	20	8	9.13	198	0.6	88	75
SED01392	8/14/92	0.16	18	5.8	8.68	231	0.4	72	102
SED01392	8/13/92	0.16	22	7	9.89	292	1.14	74	85
SED01392	9/4/92	0.16	20.8		10.3	352	1.2	59	80
Woman Creek									
SED02092	8/13/92	0.16	24	7.2	7.54	528	1.18	186	153
SED02092	9/4/92	0.16	26.5	6.2	7.32	570	1.14	172	137
SED02092	8/10/92	0.16	25	4.9	8.9	513	3.4	245	160
SED02092	9/2/92	0.16	22	9.4	8.01	521	1.21	171	158
SED02092	9/3/92	0.16	24.5	5.9	7.65	505	1.48	180	133
SED02092	8/14/92		16	7.2	6.87	385	1.4	104	82
SED02092	8/31/92	0.16	17	7.8	8.24	479	1.85	189	217
SED02092	8/12/92	0.16	15.5	9.8	8.8	534	2.64	210	170
Big Dry Creek									
SED02592	8/12/92	0.16	15	10.7	8.75	255	4.51	107	52
SED02592	8/14/92		14	8	7.23	285	5.9	172	150
SED02592	8/13/92	0.16	20	7.4	7.57	218	6.35	89	49
SED02592	8/10/92	0.16	16	7.8	8.2	174	5.6	95	49
Mower Reservoir									
SED15192	8/13/92	0.16	21	7.2	9.67	241	0.77	72	74
SED15192	8/14/92	0.16	18	7.6	9.73	235	0.5	57	76
SED15192	8/10/92	0.16	22	8.6	9.89	211	0.6	68	75
SED15192	8/12/92	0.16	19	8.2	10.2	285	0.92	71	75
SED15292	8/12/92	0.16	20	8.4	10.2	285	0.8	71	61
SED15292	8/14/92	0.16	18	8.2	10.33	240	0.3	76	71
SED15292	8/13/92	0.16	21	8.4	9.9	238	2.08	72	76
SED15292	8/10/92	0.16	22	8.2	10.4	214	0.5	65	80
Walnut Creek									
SW00292	7/18/92	0	17	8.2	6.8	191	18.1	64	41
Big Dry Creek									
SW00392	7/18/92	0	16.5	8.1	8.2	130	20.2	63	33
SW00792	7/18/92	0	14.5	8.1	7.8	231	10.5	92	61
Standley Lake									
BIO19792	9/11/92	0.16	21	7.6	8.06	196	8.71	76	50
BIO19792	8/18/92	4	22	7	7.11	241	3.38	76	48
BIO19792	8/26/92	5	21	7	8.62	217	4.72	86	47
BIO19892	8/26/92	5	21	7	8.3	222	3.6	75	38
BIO19892	9/11/92	0.16	21	7.2	7.95	181	4.6	81	51
BIO19892	8/18/92	5	22	7.4	7.67	216	3.18	78	
BIO19992	9/11/92	0.16	21	7.6	7.91	175	8.2	77	51

Table 3-3 (continued)

Sample Location	Date Collected	Depth (ft)	Water Temperature (deg. C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Turbidity (NTU	Hardness (mg/L)	Alkalinity (mg/L)
Standley Lake (continued)									
BIO19992	8/26/92	5	21	7	8.1	220	4.24	75	39
BIO19992	8/18/92	5	23	7.2	7.88	219	2.77	78	
Lindsey Pond									
LINDSEY	10/8/92		10.1		7.75	228		70	128
Standley Lake									
SD09492	7/29/92	17	21	5					
SD09492	7/29/92	0	22	7.4	7.05	265	2.73		
SD09492	7/29/92	9	22	7					
SD09692	7/29/92	9	22	7.2					
SD09692	7/29/92	17	22	7					
SD09692	7/29/92	0	22	7.6	6.5	295	2.24		
Great Western Reservoir									
SD12592	7/14/92	0	18	7.8	7.55	217	25.3	72	55
SD12592	7/14/92	20	17	7.6					
SD12592	7/14/92	10	17	7.6					
SD12692	7/14/92	20	19	7.6					
SD12692	7/14/92	0	19	8	8.3	234			
SD12692	7/14/92	10	20	7.8					
SD12792	7/14/92	40	19	6.2					
SD12792	7/14/92	20	19	6.5					
SD12792	7/14/92	30	19	6.4					
SD12792	7/14/92	0	19	7.2	6.73	244	24.8	73	60
SD12792	7/14/92	10	20	7					
Mower Reservoir									
SD15192	7/22/92	0	24	9.4	10.7	268	1.28	72	
SD15292	7/22/92	0	24.5	11	10.9	265	0.55	59	
SD15392	7/22/92	0	23.5	8.7	10.7	257	1.91	52	
Walnut Creek									
SED00392	9/2/92	0.16	19.2	8.8	5.54	531	1.8	195	213
SED00392	9/4/92	0.16	22	9.4	6.67	567	1.9	195	215
SED00392	8/13/92	0.16	22	7.9	7.46	380	4.2	197	180
SED00392	8/10/92	0.16	21	7.8	8.71	358	2.1	236	216
SED00392	8/31/92	0.16	17	8	8.53	448	0.85	164	129
SED00392	8/12/92	0.16	14	10.5	8.45	470	0.41	203	195
SED00392	9/3/92	0.16	19.8	8.3	7.56	448	2.1	190	215
SED00392	8/14/92		13	6.8	6.95	345	0.4	198	140
Standley Lake									
BIO18192	10/13/92	13.12	14.8	3.6	8.3	226	5.11	84	48
BIO18192	10/14/92	13	13.8	8.6	7.8	228	8.6	85	77
BIO18292	10/13/92	20.01	14.8	7.6	8.2	228	5.3	89	39
BIO18292	10/19/92	20.01	13.9	10	8.3	226	5.2	89	40
BIO18392	10/13/92	8.85	14.5	8.4	8.1	230	5.9	80	40
BIO18392	10/19/92	13.12	13.6	10.2	8.2	226	5.8	99	44
BIO18492	7/31/92	33	20	4.8					

Table 3-3 (continued)

Sample Location	Date Collected	Depth (ft)	Water Temperature (deg. C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Turbidity (NTU	Hardness (mg/L)	Alkalinity (mg/L)
Standley Lake (continued)									
BIO18492	7/31/92	0	23	7.6	8	177	1.4	90	52
BIO18492	10/14/92	80	14.6	5.9	8	226	4.5	81	49
BIO18492	7/31/92	0	23	7	7.45	187	1.73	73	44
BIO18492	7/31/92	16	21	6.8					
BIO18492	7/31/92	58	16	1					
BIO18492	7/31/92	29	21	6					
BIO18492	10/19/92	57.08	13.6	9	8	226	6.3	90	34
Great Western Reservoir									
BIO19192	9/1/92	5	20	5.8	6.48	206	14.27	76	45
BIO19192	9/11/92	0.16	18	6.6	6.4	220	14.24	82	41
BIO19192	8/18/92	5	24	7	8.13	193	12.66	64	47
BIO19192	8/26/92	5	20	7.4	8.4	172	15.42	67	40
BIO19292	9/11/92	0.6	19	7.4	7.52	201	11.84	66	52
BIO19292	8/26/92	5	20	7.4	8.32	168	15.2	84	39
BIO19292	8/18/92	5	23	7.4	8.08	190	13.81	69	
BIO19292	9/1/92	5	19	5.8	7.04	167	13.7	85	56
BIO19392	8/18/92	5	22	7.2	7.87	208	12.54	66	
BIO19392	9/11/92	0.16	18	6.8	7.52	181	12.55	69	38
BIO19392	8/26/92	5	20	7.8	8.3	176	16		40
BIO19392	9/1/92	5	19	5.8	7.38	161	13.35	80	48
Mower Reservoir									
BIO19492	9/11/92	0.16	20	7.4	10.36	395	0.96	63	74
BIO19492	8/18/92	4	22	7.4	10.5	266	1.16	66	87
BIO19492	9/2/92	0.16	16	8	9.65	344	1.11	80	81
BIO19492	8/26/92	5	17	8	9.8	310	0.52	70	77
BIO19592	8/18/92	4	23	7.2	10.47	250	0.75	61	
BIO19592	9/11/92	0.16	21	7.4	10.31	263	1.27	68	76
BIO19592	8/26/92	5	17	7.8	10.05	247	0.47	65	73
BIO19592	9/2/92	0.16	16.8	10	10.05	303	0.85	68	68
BIO19692	8/26/92	5	17	7.6	9.7	283	0.72	64	82
BIO19692	9/2/92	0.16	16	9	10.05	334	0.79	75	82
BIO19692	9/11/92	0.16	20	6.8	10.36	363	0.75	70	62
BIO19692	8/18/92	5	23	6	10.13	224	3.55	73	

3.6 GEOLOGY

The OU 3 study area is located on the northwestern flank of the Denver Basin on the Colorado Piedmont section of the Great Plains Physiographic province. The Colorado Piedmont is located with the high plains on the east, the Front Range on the west, the Colorado-Wyoming border on the north, and the Raton Upland on the south.

The Denver Basin is a large, north-south trending asymmetrical structural basin with rocks dipping steeply to the east along the west flank and rocks dipping more gently toward the axis of the basin along the eastern flank (Figure 3-10). The Denver Basin was formed during the late Cretaceous and early Tertiary time as part of the Laramide Orogeny when the Front Range was uplifted. The deepest portion of the basin underlies the City of Denver, where more than 13,000 feet of sedimentary rocks – including shales, sandstones, siltstones, claystones, conglomerates, and coals, ranging in age from Pennsylvanian to Paleocene – are present (DOE, 1993a).

Geologic units within OU 3 consist of unconsolidated surficial material underlain by Cretaceous sedimentary bedrock. Surficial units include Quaternary pediment and terraced alluvium, slope-wash colluvium, landslides, valley-fill alluvium, and artificial fill. Bedrock consists typically of Cretaceous claystones and sandstones of the Arapahoe and Laramie Formations; however, the Fox Hills Sandstone and Pierre Shale form an outcrop north of Rocky Flats. Figure 3-11 presents a generalized stratigraphic section of the Denver Basin.

3.6.1 Surficial Geology

Surficial deposits in OU 3 consist of unconsolidated Quaternary age units, which unconformably overlie the Arapahoe Formation and other subcropping units. The surficial deposits generally consist of four types:

- Pediment and Terrace alluvium
- Slope-wash colluvium and loess
- Landslide deposits
- Valley-fill alluvium.

Pediment and Terraced Alluvium

The pleistocene-age pediment and terraced alluvium are generally divided into five units, which are (from oldest to youngest), the Rocky Flats, Verdos, Slocum, Louviers, and Broadway alluviums. The first three are pediment gravels and commonly contain hard, cemented, calcium-carbonate layers (caliche). The last two are valley-fill and terrace deposits restricted to present-day stream drainages (Figure 3-12).

<u>Rocky Flats Alluvium</u> - Rocky Flats is located on a terrace capped by Rocky Flats Alluvium, which is the oldest and topographically the highest of the surficial deposits in the area. The Rocky Flats Alluvium is a series of laterally coalescing alluvial fans deposited by streams and occupies an extensive erosional bedrock surface beneath Rocky Flats. The alluvium ranges from 0 to 100 feet in thickness and is thickest west of Rocky Flats near the apex of the alluvial fan and thinnest just east of Rocky Flats near the depositional limit of the fan. Bedding is uncommon and the alluvium is composed of poorly sorted boulders, cobbles, pebbles, and sand in a yellowish brown to red clayey matrix, with layers of clay, silt, and sand. The pebbles, cobbles, and boulders are composed of quartzite, but include lesser amounts of

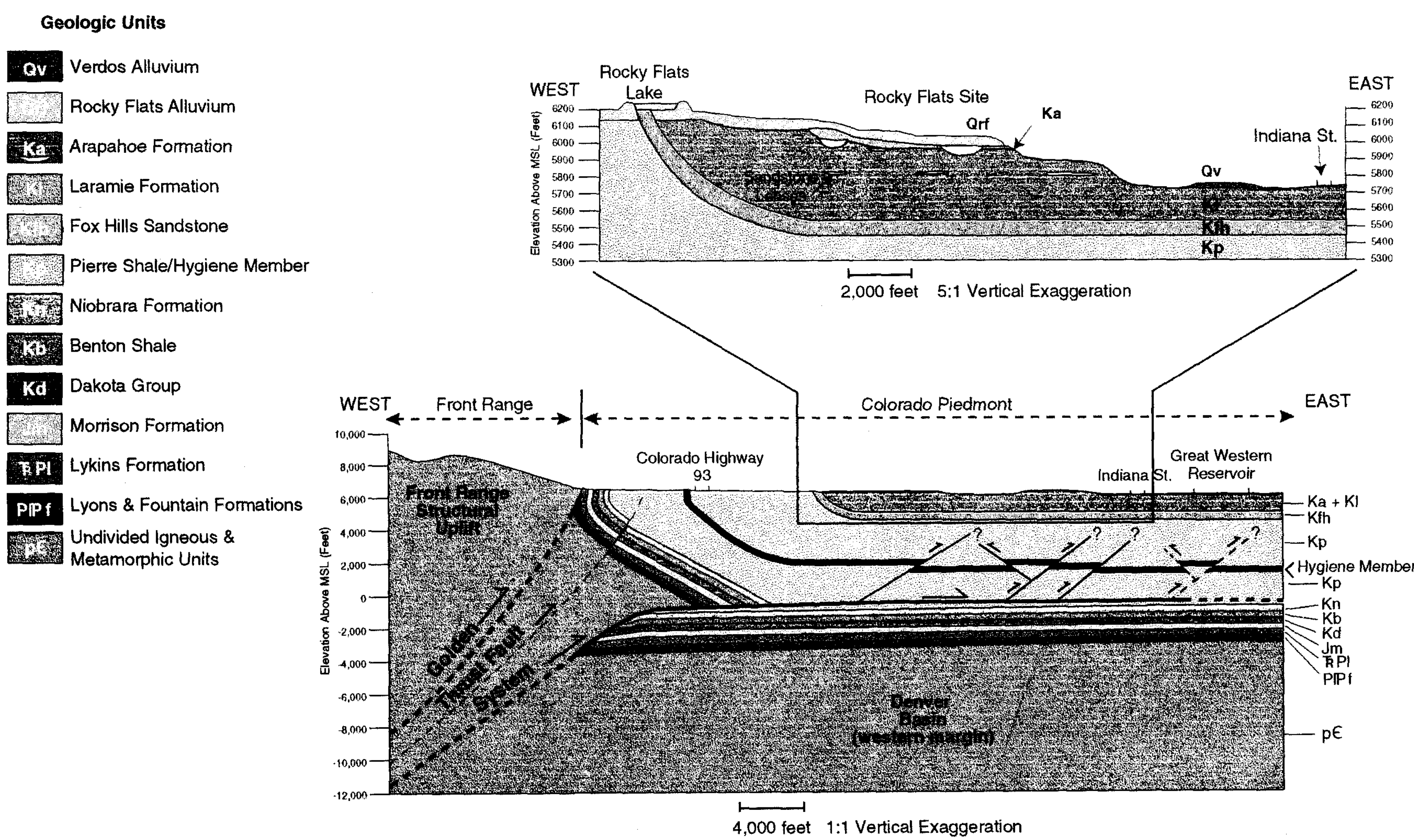


Figure 3-10 Generalized Geologic Cross Section of the Front Range and the Rocky Flats Area (from EG&G, 1993a).

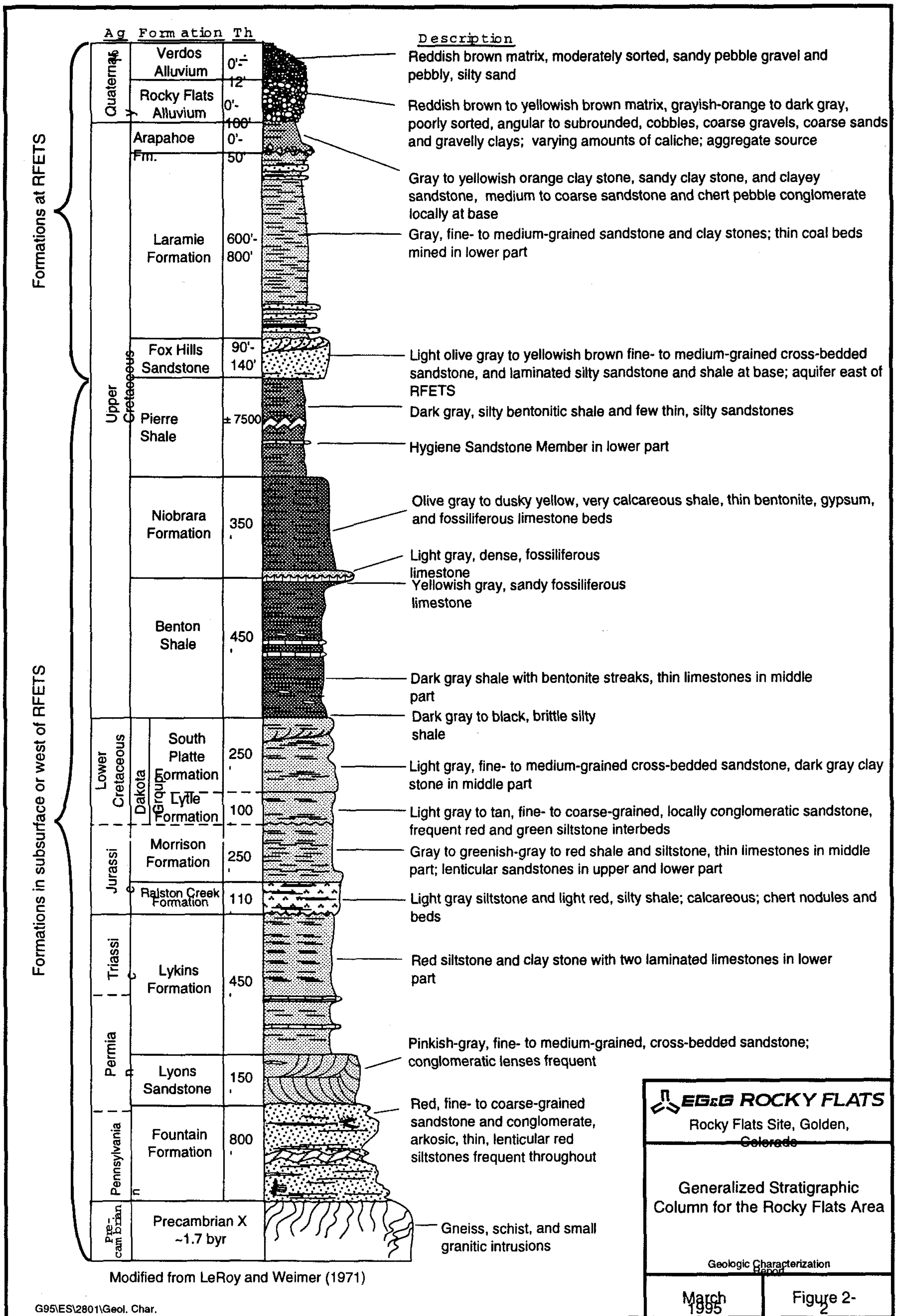


Figure 3-11
General Stratigraphic Column for the Rocky Flats Area

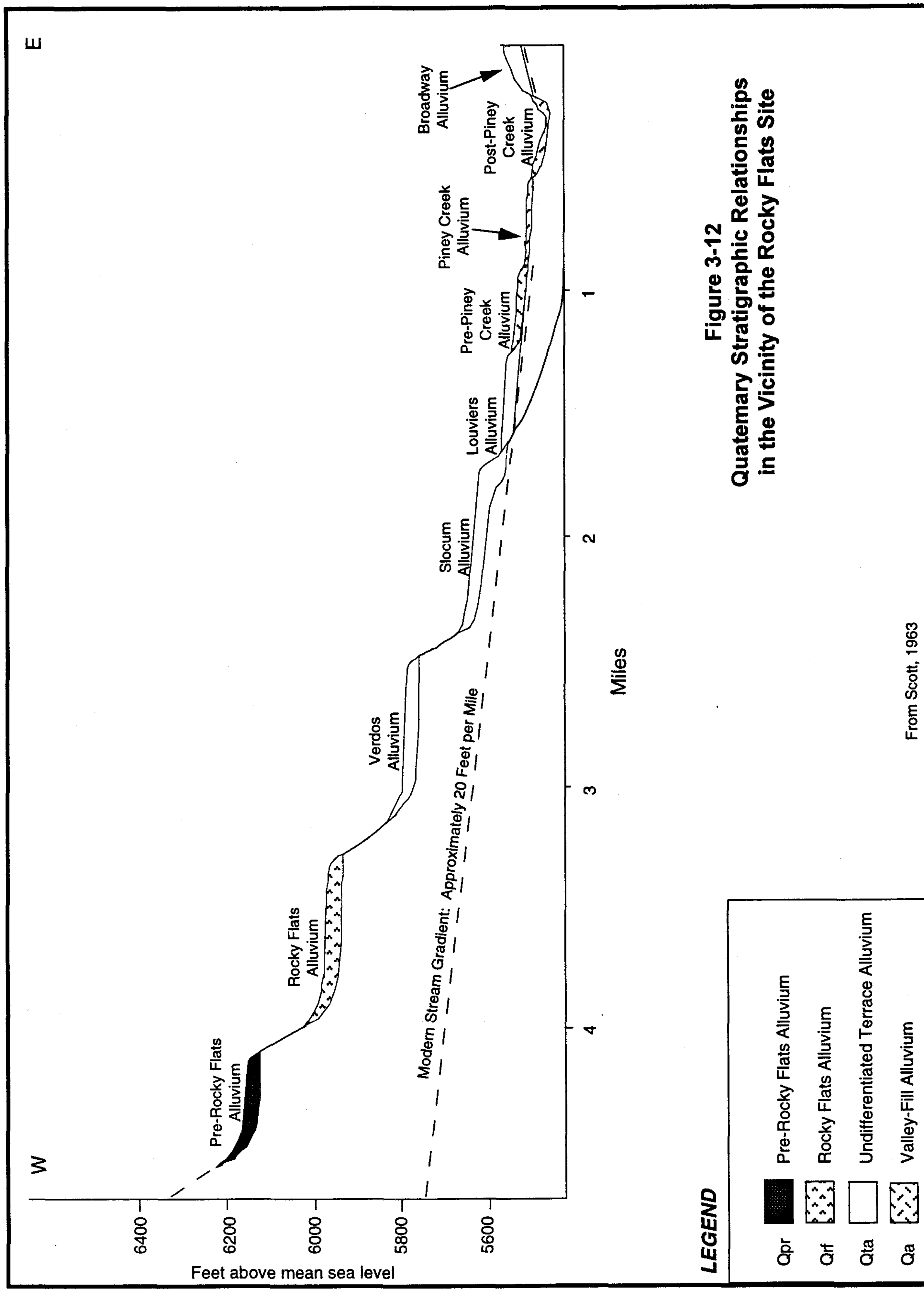


Figure 3-12
Quaternary Stratigraphic Relationships in the Vicinity of the Rocky Flats Site

schist, gneiss, granite, pegmatite, siltstone, and sandstone. Gravels range from 2 to 4 inches (5 to 10 cm) in diameter, with boulders as large as 2 feet (0.61 m) in diameter (EG&G, 1992). The unit is weakly to moderately cemented with caliche (calcium carbonate) in some areas. The Rocky Flats Alluvium is breached in major drainages (e.g., Woman Creek), exposing the claystones, siltstones, and sandstones of the underlying Arapahoe/Laramie formation. The Rocky Flats Alluvium lies along Upper Church Ditch in the northern portion of the OU 3 study area.

Verdos Alluvium - Most of the Verdos Alluvium has been removed by erosion at Rocky Flats. It is, however, found in the OU 3 study area between Standley Lake and Great Western Reservoir. It is also found south of Standley Lake. It is generally 15 to 30 feet thick and consists of fairly well stratified brown boulders, cobbles, and coarse sands weakly cemented by clay and calcium carbonate. Many gravel clasts are weathered and crumble when handled.

Slocum Alluvium - The Slocum Alluvium is similar to the Verdos Alluvium in lithology and texture, but is generally more fine-grained than the Rocky Flats and Verdos alluvial deposits. It is moderate reddish-brown, well-stratified cobble gravel and clayey coarse sand containing abundant mica. The Slocum Alluvium is found along portions of Women Creek and Smart Ditch at OU 3.

Louviers Alluvium - The Louviers Alluvium ranges in thickness from 3 to 20 feet, and consists of slightly weathered, fairly well sorted, stratified red to yellowish-brown sand, arkosic pebbles and cobbles in a clayey silt to sandy matrix. The Louviers Alluvium is found along Woman Creek.

Broadway Alluvium - The Broadway Alluvium is as much as 30 feet thick and consists of yellowish-orange to reddish-brown, fine to coarse grained sand and pebbles (less than 1 inch) of predominantly Precambrian crystalline rock. The Broadway Alluvium is not extensive in the OU 3 study area.

Loess and Slope Wash Colluvium

Slope-wash colluvium is of middle Pleistocene to upper Holocene age. It was deposited by slope wash and gravity induced downward creep on steeper slopes of Rocky Flats alluvium and bedrock material. The colluvium is heterogeneous and consists of clay with lenses of silt, sand, and gravel. Colluvial deposits are present on valley hillsides inside and east of the Rocky Flats Alluvium along Walnut and Woman Creeks (DOE, 1993a).

Pleistocene to Holocene loesses consist of wind-transformed silts. Loess deposits have been mapped on the higher alluvial terraces south of Standley Lake. The loess deposits are typically silty sands or sandy silts that are clayey.

Landslide Deposits

Landslide deposits are middle Pleistocene to Holocene deposits present along steep hillsides in the incised drainages. These deposits range from 10 to 100 feet in thickness and are most numerous in the Rock Creek drainage.

Valley-Fill Alluvium

Valley-fill alluvium is a Holocene alluvium that fills the modern stream valleys of Woman Creek, parts of Walnut Creek, and Big Dry Creek. These valley-fill deposits include Piney Creek alluvium, which consists of brownish-gray silt, sand and clay with interstratified humic-rich layers. Some lenses of gravel may be present.

3.6.2 Bedrock Geology

Cretaceous-aged formations in the vicinity of OU 3 were deposited during the Laramide Orogeny. Uplifted strata to the west provided the source material for the prograding sequence of Fox Hills delta-front sand, Laramie delta-plain coastal sediments, and the fluvial deposits of the Arapahoe Formation.

Arapahoe Formation

The Arapahoe Formation was deposited in a low-sinuosity, braided stream environment. It consists mostly of channel/bar deposits, with lesser amounts of overbank and flood-plain deposits. The deposits consist predominantly of light to medium olive-grey and olive-black claystones and silty claystones, as well as siltstones and sandy conglomerates. If they are weathered at the base of the alluvium, the claystones will appear dark yellowish-orange as a result of iron-oxide staining below the unconformable contact between alluvium and bedrock. Staining is common at depths of 1 to 20 feet below the alluvium (EG&G, 1991c). Caliche may also be found in this weathered zone in sandstones beneath the Rocky Flats Alluvium, and above claystones or siltstones, as a result of reduced percolation and high evaporation.

The Arapahoe Formation is the uppermost bedrock unit in the vicinity of OU 3. It unconformably underlies the surficial materials beneath most of the area. A major erosional surface developed in the site area during late Tertiary time, completely removing two formations overlying the Arapahoe Formation and eroding into the Arapahoe. Weathering penetrates the Arapahoe Formation beneath surficial deposits to a depth of 10 to 40 feet (3 to 12 m) (DOE, 1993a). Drainages eroded into the Arapahoe formation were infilled by later surficial deposits. The top of the bedrock surface beneath the surficial deposits generally parallels the ground surface topography, with bedrock lows along existing drainageways and creeks (EG&G, 1990a).

Laramie Formation

The Laramie Formation underlies the Arapahoe Formation and comprises two units: a thick upper unit composed of claystone with some siltstones and sandstones and a lower unit containing numerous coals and sandstones that increase in thickness toward the base of the unit. The contact with the overlying Arapahoe Formation is conformable and is defined on the basis of textural and lithologic characteristics. The upper Laramie consists mostly of silty claystones, siltstones, and some fine-grained fluvial channel sandstones. The basal 150 feet of the upper Laramie interval contains coal beds that range from 1 to 3 feet in thickness. The silty claystones are light olive-gray to olive-black, massive, and may contain sand or carbonaceous material. Iron-oxide nodules occur within siltstones (EG&G, 1991c).

The lower Laramie is composed of sandstones, siltstones, claystones, and coal beds. The sandstones are finer grained and more laterally continuous than those found in the Arapahoe Formation. Coal beds range from 2 to 8 feet in thickness, and one of the sandstone beds is approximately 50 feet thick (EG&G, 1991c).

In the vicinity of Rocky Flats, the Laramie Formation is approximately 600 to 800 feet thick and has been informally divided into two members. The upper Laramie ranges in thickness from approximately 300 to 600 feet and consists mainly of structureless, olive-gray to yellowish-orange kaolinitic claystones with large ironstone nodules. The lower Laramie is approximately 300 feet thick and is composed of kaolinitic claystones, sandstones, and coal beds (EG&G, 1995). The beds within the Laramie Formation dip approximately 45 to 50 degrees in areas west of Rocky Flats and flatten to less than a 2-degree dip in the OU 3 are (EG&G, 1990a,c).

3.6.3 Structural Features

The area where OU 3 is situated was tectonically active during the Laramide Orogeny (approximately 45 to 60 million years ago). Structural activity was manifested mainly as thrust faults resulting from compressional stresses. After a period of quiescence, the tectonic forces shifted from a compressional to an extensional regime, characterized by tensional faulting from the Miocene to the Pliocene period (5 to 25 million years ago). The period of faulting produced the normal and high-angle reverse faults associated with the present-day Front Range.

OU 3 lies on a monoclinal fold that trends along the eastern margin of the Front Range; the axial plane of the fold strikes roughly north-south. To the west, steeply east-dipping strata of Pennsylvanian age lie unconformably on Precambrian granitic rocks.

3.7 HYDROGEOLOGY

The Rocky Flats Alluvium, other unconsolidated surficial deposits, weathered bedrock claystones, and weathered subcropping Arapahoe sandstones (i.e., the "number one" sandstones) are in hydraulic connection and together represent the upper hydrostratigraphic (UHSU). The UHSU is largely and unconfined flow system. The unweathered claystones and sandstones and unweathered Arapahoe and Laramie formations have significantly lower hydraulic conductivities than the materials comprising the UHSU, and represent a lower flow system called the lower hydrostratigraphic unit (LHSU).

3.7.1 Upper Hydrostratigraphic Unit

In the spring and early summer, the Rocky Flats alluvium and Arapahoe formation, located in the central and eastern portion of Rocky Flats, are recharged by precipitation and lateral groundwater flow. During these periods of high flow, surface water is lost to bank storage in the Valley Fill alluvium, and returns to the stream after the runoff subsides. In the stream drainages, groundwater discharges at seeps, which are common at the base of the Rocky Flats alluvium and where individual sandstones become exposed to the surface.

In the western portion of Rocky Flats, where the thickness of the alluvial material is greatest, the depth to the water table is 50 to 70 feet below the ground surface (EG&G, 1991c). The water table becomes shallower to the east (with local variations) as the alluvial material thins. In the late summer and early fall these formations are recharged mostly by lateral groundwater flow.

Groundwater movement in the Rocky Flats alluvium is generally from west to east and is controlled by pediment drainages cut into the top of bedrock. Flow is downslope through colluvial materials and then along the course of the stream in valley-fill materials. The alluvium terminates approximately 1,500 feet west of the eastern Rocky Flats boundary and does not directly supply water to wells located downgradient of Rocky Flats at OU 3. Discharge from the alluvium occurs at seeps located at the contact between the alluvium and bedrock along the edges of the valleys. Most seeps flow intermittently. A schematic of the groundwater and surface water interaction is presented in Figure 3-13. The figure

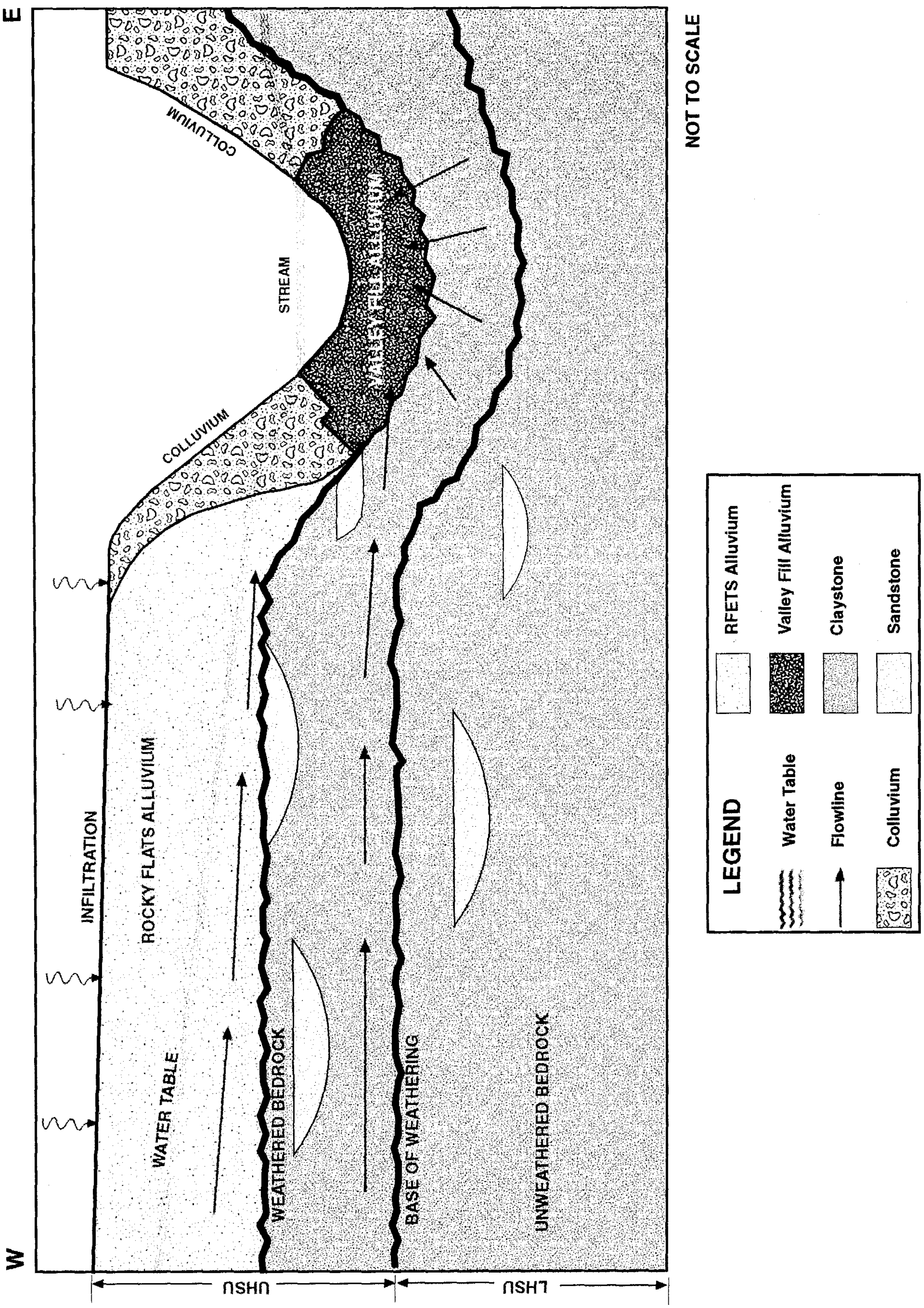


Figure 3-13 **Schematic of Groundwater & Surface-Water Interaction**

depicts conceptually how groundwater flows in the alluvium and colluvium discharge to the stream. Vertical gradients are generally downward in the UHSU.

3.7.2 Lower Hydrostratigraphic Unit

The LHSU comprises all lithostratiographic units in the unweathered portions of the Arapahoe and upper Laramie formations, except for subcropping sandstones at the alluvial/bedrock unconformity. In general, saturated sandstones that lie within the unweathered claystones and siltstones of the Arapahoe or Laramie formations are confined units that lack lateral continuity (EG&G, 1995a)

The rate of groundwater flow in the LHSU is controlled by the hydraulic conductivity of the unweathered bedrock and by the hydraulic gradient. The confining claystones and siltstones of the LHSU are much less permeable than the lithostratigraphic units of the UHSU. Hydraulic conductivities of unweathered claystone range from approximately 10^{-6} to 10^{-8} cm/sec, with a geometric mean of 2.48×10^{-7} cm/sec. Unweathered sandstone units of the LHSU are slightly more permeable, with a mean hydraulic conductivity of 5.77×10^{-7} cm/sec.

The main recharge area for Arapahoe sandstones is under Rocky Flats alluvium, although some recharge from the colluvium and Valley Fill alluvium may occur along the stream valleys. Recharge is greatest during the spring and early summer when rainfall and stream flow are at a maximum and, during this season, water levels in the Rocky Flat alluvium are relatively high. Discharge areas are located at the edges of valleys. Groundwater flow in the bedrock is from west to east, although flow within individual sandstones is controlled locally by the channel geometries. Table 3-4 gives the relative hydraulic conductivities associated with the lithologic units present at OU 3.

The lower sandstones of the Laramie formation, together with the sandstones and siltstones of the underlying Fox Hills Sandstone, comprises a regionally important aquifer in the Denver Basin known as the Laramie/Fox Hills aquifer. Near the center of the basin the aquifer thickness ranges from 100 to 200 feet, with no pronounced regional trends. Recharge to the Laramie/Fox Hills aquifer infiltrates through a rather limited outcrop area exposed to surface-water flow along the Front Range (Robson et al., 1981). Claystones of the Laramie Formation have very low hydraulic conductivities; therefore, the U.S. Geological Survey (Hurr, 1976) concluded that Rocky Flats operations would not impact any units below the upper claystone unit of the Laramie Formation.

The present understanding of the hydrogeologic relationships at Rocky Flats indicates that there are no known bedrock pathways through which groundwater contamination may directly leave and migrate into the confined aquifer system present at OU 3 (EG&G, 1995b).

3.7.3 OU 3 Hydrogeology

Before two groundwater monitoring wells were installed during the OU 3 field investigations, there were no dedicated groundwater monitoring wells outside of the site eastern boundary. Although it is known that numerous privately-owned water wells have been drilled just east of Rocky Flats, limited information is available from drilling and filing records held by the Colorado Division of Water Resources. These records suggest that the thickness of surficial deposits ranges from 15 to 50 feet (4.6 to 15 m) and averages approximately 25 feet (7.6 m) near the remedy lands. Surficial deposits typically are described in the well records as clay, sandy clay, or clay with gravel and boulders, all locally covered by 5 or 6 feet of topsoil.

The underlying bedrock is described in the well records as alternating layers of shale and sandstone, which is assumed to be a very generalized description of the Arapahoe Formation. Most of the wells studied were completed in sandstones at depths ranging from 35 to 275 feet (10.7 to 84 m). Static water levels averaged 10 to 50 feet (3 to 15 m) higher than the screened interval, indicating moderate pressure head in the sandstones (confined conditions). In one well, completed in the shallow alluvium in the southwest corner of Section 6, just north of the remedy lands (DWR, 1990) the static water level was 20 feet (6.1 m).

As noted previously, two monitoring wells were installed in OU 3 during the field investigation. One well is located east of Standley Lake and one well is east of Great Western Reservoir. In the Standley Lake monitoring well (Well 49292), the alluvium/bedrock interface was encountered at an elevation of approximately 5387 feet (12.8 feet below the ground surface). The well is completed in a silty sandstone unit of the Arapahoe Formation and is screened from 29 to 44 feet below the ground surface. The well is under positive pressure (flowing).

Table 3-4
Hydraulic Conductivities of OU 3 Lithologic Units

Lithologic Unit	Hydraulic Conductivity (Geometric Means)
Rocky Flats Alluvium	2.06×10^{-4} cm/sec
Subcropping Arapahoe Sandstones	7.88×10^{-4} cm/sec
Unweathered Sandstones	5.77×10^{-7} cm/sec
Weathered and Unweathered Claystones	2.48×10^{-7} cm/sec

In the well installed east of Great Western Reservoir, the alluvium/bedrock interface was encountered at an elevation of approximately 5533.5 feet (11 feet below the ground surface). The well is completed in a silty sandstone unit of the Arapahoe Formation and is screened from 24 to 34 feet below the ground surface. During sampling, the well was purged dry and slowly recovered.

3.8 ECOLOGICAL SETTING

The ecological setting of OU 3 comprises both aquatic and terrestrial ecosystems. Of the terrestrial ecosystems, the grasslands are the most predominant (as shown in Figure 3-14). The aquatic ecosystems have both lentic and lotic environments. Lentic environments are characterized as still bodies of water, such as lakes or reservoirs. Conversely, lotic environments are characterized as flowing bodies of water, such as creeks and drainages. The primary water bodies of concern for the OU 3 evaluation include the lower reach of Woman Creek, Walnut Creek, and Big Dry Creek, as well as Mower Reservoir, Great Western Reservoir and Standley Lake. The following subsections provide a summary of the ecology within the OU 3 area. Further detail regarding habitat characteristics and species occurrence are presented within the Ecological Evaluation (Appendix B).

3.8.1 Terrestrial Ecosystem

The terrestrial ecosystems observed at Rocky Flats and the surrounding area are typical of the High Plains short and mid-grass prairie grasslands of Colorado. Plant and animal communities are adapted to a high plains grassland and drainages. The drainages are ephemeral creeks with a mixture of mesic grasslands and wetlands with some riparian zones along lower creek bottoms. Reservoirs and ditches constructed in drainages have replaced the natural drainage system and most riparian zones. Sparse cottonwood groves and isolated trees grow in the lower drainages and around reservoirs. Vegetation and animals in these ecosystems have been fragmented and altered by human activities and land use. The most extensive remaining semi-natural ecosystems are upland xeric grasslands that were previously grazed. The prairie grassland provides a large expanse of habitat, but cover is limited and habitat diversity has been seriously degraded by a long history of livestock grazing. Wildlife at Rocky Flats is typical of species found in similar habitat types throughout the foothills of the Front Range of the Rocky Mountains. Figure 3-14 presents a summary of habitat types for the OU 3 area.

The existing terrestrial habitats within OU 3 have been extensively modified by land use and development patterns, and therefore have no natural ecosystem. Land uses and continuing management practices that have altered terrestrial habitats include agriculture (plowing); remediation of contaminated soil surfaces by deep chiseling; construction of the three reservoirs and the ditches and drainages for water control; and the construction of roads, powerlines, railroad grades, housing, and commercial developments. Other land-use practices that have directly or indirectly altered habitats are grazing by domestic livestock, irrigation, introduction of weeds and exotic plant species, elimination of predators, and changes in pest control. Land-use changes are continuing with the abandonment of plowed fields, removal of domestic grazing, creation of open spaces, and revegetation of remediated soils.

The major habitat type on the uplands outside the agriculture fields and reservoirs, is altered grasslands (short, xeric mixed, and mesic mixed grassland habitat types). The upland grasslands are concentrated on the ridges and slopes east of Rocky Flats along Indiana Street. They are either being presently grazed by livestock or have been heavily grazed in the recent past,which has affected species composition and condition. Low-growing grasses, introduced grasses, and weedy species are common. Recent intensive activity by large prairie-dog populations has reduced many grassland habitats to a weedy/forb stage. The 250-acre remediation area (part of IHSS 199) within OU 3 has not been effectively revegetated.

The most important wildlife habitats within OU 3 are associated with the permanent water provided by reservoirs and other small impoundments, and the riparian-zone cottonwood trees. Wetlands and riparian habitats along drainages are small and controlled by water diversions and releases. Small wetlands along drainages and the edges of reservoirs are a short or tall marsh habitat type, but may be seasonally dry due to water control and flow fluctuations. The riparian habitats consist of narrow zones of shrubland in the upper drainages such as Woman Creek and the ditch leading to Mower Reservoir, or of single rows of cottonwood trees along the lower broader drainages.

A variety of herbivores (plant eaters) provide a diverse selection of prey for the carnivores (meat eaters). Common reptiles inhabiting OU 3 include bull snakes, rattlesnakes, racers, and eastern short-horned lizards, all of which are found in many habitats at OU 3, whereas western painted turtles and western plains garter snakes reside near moist habitats. Common birds include western meadowlarks, horned larks, red-winged blackbirds, mourning doves, vesper sparrows, house finches, marsh hawks, red-tailed hawks, ferruginous hawks, rough-legged hawks, and great horned owls. Mallards and Canada geese use the small ponds as feeding and breeding areas. The most abundant medium-sized mammals are black-tailed prairie dogs, desert cottontails, and muskrats, along with a few black-tailed jack rabbits, whitetailed jack rabbits, and porcupines. Mule deer are the largest mammal at OU 3 and roam throughout most habitats. Coyotes, striped skunks, raccoons, and long-tailed weasels are the common carnivores, with badgers and red foxes observed occasionally. Gray foxes, bobcats, and mountain lions have been reported at OU 3, but, were not observed during the baseline study.

Animal species that may be primary receptors of contamination are the ground-dwelling rodents. Larger animals, such as deer and raptors, use the study area but are wide-ranging and not confined to OU 3. In general, wildlife access to OU 3 is restricted by roads, fences, residential and commercial development, and the intrusion of human activities.

3.8.2 Aquatic

The lotic OU 3 environments of interest for this study (Woman Creek, Walnut Creek, and Big Dry Creek) are subject to fluctuations in flow rates because of precipitation events as well as reservoir releases (Walnut Creek and Big Dry Creek only). Therefore, the biotic community within these streams is characterized by opportunistic species (such as minnows, suckers, dace, etc.). The benthic macroinvertebrate populations are also influenced by flows. The internal and external stream structures are affected by the flow regime,which controls stream-side vegetation and riparian structure. Most of the riparian vegetation is characterized by willows and cottonwoods, as well as other shrub and grass species. Floods have scoured the riparian environment in certain areas. In addition, the fluctuating flows have created undercut banks and siltation within the streambed.

The lentic environments evaluated as part of the OU 3 RI included Mower Reservoir (IHSS 202), Great Western Reservoir (IHSS 200), and Standley Lake (IHSS 201). Mower Reservoir is privately owned and stocked with smallmouth bass. Other species that occur include minnows and suckers. Great Western Reservoir is not available for public recreational use, therefore the resident fish populations consist of opportunistic species such as carp, white mountain suckers, and minnow species. Standley Lake is a recreational lake that the Colorado Division of Wildlife has enhanced with a diversity of game fish species including rainbow trout, gizzard shad, catfish, and yellow perch. Additional species of minnows, shiners, suckers, and carp are also present.

Mower Reservoir is characterized by an abundance of emergent and submerged vegetation. An abundance of daphnia and snails were also noted. Vegetation occurs throughout the reservoir because the depth rarely exceeds 6 feet. The water has a high clarity with a fluctuating pH (see Subsection 3.5), potentially as a result of the high photosynthesis rate caused by the abundance of vegetation.

Both Great Western Reservoir and Standley Lake contains similar plant and invertebrate species assemblages typical of reservoir systems. Plant communities are exceptionally successful in areas with minimal human activity. Otherwise the lakes are virtually devoid of any plant species. The water clarity within the reservoirs is highly dependent upon wave action. Winds create a high water turn over, which in turn liberates sediment and creates moderately turbid environments, especially along the shoreline. Standley Lake stratified during these sampling efforts when severe environmental temperature changes occurred. Sudden changes also affect the biotic structure; few invertebrate species were found within the maximum depth areas in because to anoxic conditions were created by the stratification.

4.0 NATURE AND EXTENT OF CONTAMINATION

The detailed medium-specific evaluations presented in this section focus on the nature and extent of contamination including a comparison to background/benchmark data, summary statistics, and spatial analysis. Included in this section is a discussion of the OU 3 data usability evaluation (that includes evaluation of data protocols and precision, accuracy, representativeness, completeness, and comparability [PARCC]), a summary of background/benchmark data sets, and a summary of the nature and extent of contamination for each medium (i.e., soils, surface water, sediments, groundwater, and air).

The OU 3 data were compared to background and literature data to determine if these data are above background levels or within naturally-occurring ranges. The evaluations compared the OU 3 mean and maximum concentration values to the background and literature mean and maximum values. If the OU 3 mean concentration was greater than the upper-bound background value (i.e., mean plus two standard deviations) and the OU 3 maximum concentration value was greater than the background maximum value, the analyte concentration was considered to be elevated. The OU 3 data were also evaluated spatially to identify whether patterns of chemical concentrations indicated natural variability or contamination. For assessing drainage and reservoir sediments, probability plot analysis were performed for PCOCs.

A summary of the nature and extent of contamination for OU 3 is presented in Table 4-1. This table summarizes the data needs prescribed in the OU 3 Work Plan, the activities performed during the OU 3 RFI/RI, the use of the data, and the analytical results by medium. The OU 3 field investigation analytical results indicate that concentrations of plutonium-239, -240 and americium-241 were observed above background levels in the Remedy Lands surface soils, located east of the Rocky Flats eastern boundary. In addition, elevated concentrations of plutonium-239, -240 were observed in subsurface sediments of Great Western Reservoir. Concentrations of copper were observed above background in Great Western Reservoir subsurface sediments and potassium was elevated in Mower Reservoir subsurface sediments. Elevated concentrations of arsenic, cadmium, copper, lead, manganese, mercury, nickel, potassium, silver, and zinc were observed in Standley Lake subsurface sediments. No analytes were detected at concentrations above background levels in the surface water of Great Western Reservoir, Standley Lake, or Mower Reservoir. In groundwater, potassium and strontium were elevated slightly above background levels.

The COC selection process for the HHRA is a prescribed process (agreed upon by DOE, EPA, and CDPHE) that was designed to identify analytes that may contribute significantly to human health risks and therefore, require further evaluation in the HHRA. For OU 3, this process includes a statistical comparison of OU 3 data to background data, elimination of essential nutrients, elimination of chemicals detected infrequently (less than 5 percent detection frequency), a concentration-toxicity screen, a comparison to preliminary remediation goals (PRGs), and a weight-of-evidence background comparison evaluation (applied to analytes for which a statistical background comparison was not appropriate). Details and results of the COC selection process are presented in Technical Memorandum No. 4, Human Health Risk Assessment Chemicals of Concern Identification, Operable Unit 3 (TM 4) (DOE, 1994d), and in the HHRA presented in Appendix A of this report.

4.1 DATA USABILITY AND DATA EVALUATION PROTOCOLS

The OU 3 database is formatted as a set of independent Paradox (DOS Version 4.0 RDMS) tables containing fields of data. Figure 4-1 shows the sources of data and the general procedures that were followed to develop the OU 3 database. The OU 3 database consists of data from the following sources:

- RFI/RI sampling effort
- 1983/84 sediment investigations
- Remedy Lands soil data
- Background Geochemical Characterization Report
- Rock Creek background soil data

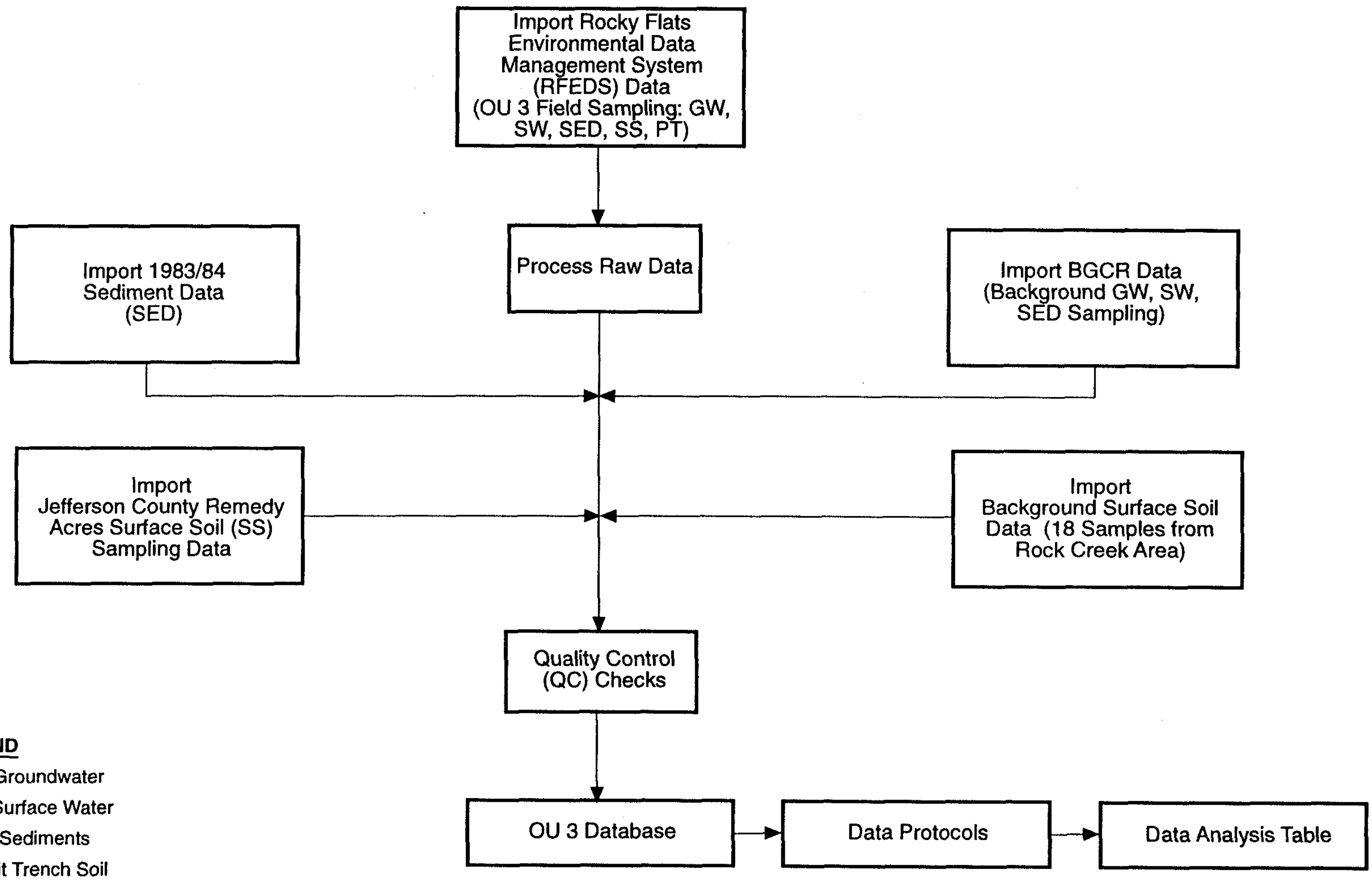
The set of data retrieved from the Rocky Flats Environmental Data Management System (RFEDS) for use in this report was received on February 15, 1994. Appendix F contains descriptions of the tables and fields of data, as well as a detailed discussion of the data sources and procedures used to develop the OU 3 database. The complete OU 3 analytical results database is provided on computer diskette in Appendix E.

Data usability levels for data used in the RFI/RI evaluations were determined with validation codes assigned to each data record by the independent data validators. In accordance with data usability guidance for the Environmental Restoration Program at the site (DOE, 1994b; EPA, 1989a; EPA, 1990), any data records that contain an "R" (i.e., rejected by the independent validators) in the validation code field were considered unusable for the RFI/RI evaluations. All other data were considered acceptable for use in the RFI/RI evaluations. Ninety-five percent of the validated data for surface soil, sediment, surface water, and groundwater (a total of 14,690 data records) were classified as usable. Table 4-2 summarizes the results of the data validation process by the environmental medium and analytical test group.

Any nonvalidated data in the OU 3 database were assumed to be usable and therefore were included in the data set for the RFI/RI evaluations. Ninety-three percent (1,082 data records) of the surface soil, sediment, surface water, and groundwater data used in the RFI/RI evaluations were validated for this report.

Data evaluation protocols were developed based on Guidance for Data Usability in Risk Assessments (EPA, 1990) and a guidance memorandum from EG&G (EG&G, 1994b). The protocols were designed to identify and eliminate data considered unusable for quantitative data analysis. Additionally, the protocols provide for consistent treatment of nondetects, QC samples, and other specific categories of data in the quantitative data analysis. A Data Analysis database table was created as part of the OU 3 database for use in quantitative data analysis tasks that reflect application of the data-evaluation protocols. The data-evaluation protocols and the procedures followed to create the Data Analysis table are described in detail in Appendix F.

As described in Section 2.0 of this report, each OU 3 surface soil plot was sampled by two methods: the Rocky Flats method and CDPHE method. In the OU 3 database, the results of these two sample methods



LEGEND

GW = Groundwater
SW = Surface Water
SED = Sediments
PT = Pit Trench Soil
SS = Surface Soil
BGCR = Background Geochemical Characterization Report (DOE, 1993c)

Figure 4-1
OU 3 Database Preparation

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Table 4-2
Data Validation Summary

Medium Analytical Test Group	Total Number of Records in Database	Number of Validated Records in Database	Number of R-Validated Records in Database[a]
Surface Soil			
Radionuclides	658	568 (86%)	31 (5%)
Total	**658**	**568 (86%)**	**31 (5%)**
Sediment[b]			
Metals	6,405	6,208	302
Radionuclides	1,937	1,855	121
Volatile Organic Compounds	616	578	227
Physical Parameters	241	162	18
Total	**9,199**	**8,803 (96%)**	**668 (8%)**
Surface Water			
Dissolved Metals	1,362	1,177	11
Dissolved Radionuclides	323	323	45
Total Metals	1,522	1,488	12
Total Radionuclides	395	394	55
Pesticides	126	104	0
Volatile Organic Compounds	340	340	10
Water Quality	708	652	3
Total	**4,776**	**4,478 (94%)**	**136 (3%)**
Groundwater			
Dissolved Metals	464	348	6
Dissolved Radionuclides	41	35	0
Total Metals	464	348	3
Total Radionuclides	42	30	0
Water Quality	128	80	0
Total	**1,139**	**841 (74%)**	**9 (1%)**
Total — All parameters and all media	**15,772**	**14,690 (93%)**	**844 (1%)**

[a]R-Validated = Rejected by data validation process.
[b]Sediment numbers include grab (surface) and core (subsurface) data.
Source: OU3 Database (DB081094.8b).

(for each sample location) were averaged after a statistical comparison indicated no statistical difference in the results between the two methods. Results of the statistical comparison are provided in Appendix F.

4.1.1 PARCC Summary

In Section 5.0 of the OU 3 Work Plan, data quality objectives (DQOs) were identified for the OU 3 RFI/RI project. Appendix G presents the results of the OU 3 data quality and usability evaluation with respect to the established DQOs. The PARCC of the data set were evaluated separately to determine overall data quality and data usability. The results of the PARCC analysis indicate that the DQOs were satisfied by the sampling and analysis effort conducted for OU 3.

To ensure compliance with DQOs, protocols from *Evaluation of ERM Data for Usability in Final Reports* (EG&G, 1994b) were followed. These procedures are based on requirements set forth in the *Quality Assurance Project Plan Manual* (EG&G, 1989) and *DOE Data Management Requirements* (DOE, 1993c). Although occasional sample- and analyte-specific exceedances of the objectives were noted, these exceedances were judged to be either random or related to analytical limitations (radionuclides) and not related to sampling. No project-wide systematic trends were noted that would affect the overall quality or usability of the data. Other than the data rejected and excluded from the database for independent data validation reasons, no additional data were excluded from further consideration in the RFI/RI report based on the PARCC analysis (see Appendix G).

4.2 BACKGROUND/BENCHMARK DATA SETS

The term "benchmark data" is used in this report to indicate the data compiled from literature and other data sources referenced in Table 4-3 that represent background conditions within the Front Range of the Rocky Mountains and Colorado. The term "background data" is used to represent the data collected and summarized in DOE (1993a, 1993b) and EPA (1992a). Of the environmental media in OU 3, only soil had background data suitable for statistical comparisons.

A search was performed to gather benchmark literature data for the comparison of OU 3 sediment and surface water data. As shown in Table 4-3, more than 20 sources were contacted to obtain benchmark data for sediments and surface water. The data gathering effort focused on obtaining reservoir and lake data in the Front Range of the Rocky Mountains and Colorado.

The Background Geochemical Characterization Report was prepared by the DOE in September 1993. The goal of this report was to "provide...background data necessary to identify concentration levels of various chemicals that may indicate contamination at the RFP" (DOE, 1993a). The original applicability of this report extended to all operable units; however, it was concluded that these data were not appropriate for statistical comparisons for all media in OU 3. Information from the Background Geochemical Characterization Report was evaluated both quantitatively and qualitatively to identify if an analyte is present at concentrations above background levels.

4.2.1 Soils

From February 1992 to March 1993, eighteen surface soil samples were collected from the northwest area of the Rocky Flats property in the vicinity of the Rock Creek drainage (Figure 4-2). This area is located in the buffer zone and is generally considered upwind and upgradient of industrial activities associated with Rocky Flats.

Table 4-3
Front Range Sources Contacted as Part of Benchmark Data Collection Activities

Source	Media	Parameter(s)
Aurora Reservoir Water Quality Control	Surface Water	Metals
Arvada Department of Water and Environmental Quality	Surface Water	Metals
Background Geochemical Characterization Report	Surface Water	Metals/Radionuclides
Bear Creek Water and Sanitation District	Surface Water	Metals/Radionuclides
Boulder Department of Water and Environmental Quality	N/A	N/A
Broomfield Department of Water and Environmental Quality	N/A	N/A
Chatfield Basin Authority	Surface Water	Metals
Cherry Creek Basin Authority	Surface Water/Sediment	Metals/Radionuclides
Colorado School of Mines	Sediment	Radionuclides
Coors Brewing Company	N/A	N/A
Denver Regional Council of Governments	Surface Water/Sediment	Metals/Radionuclides
Final Historical Information Summary and Preliminary Health Risk Assessment OU 3 (DOE, 1991b)	Sediment	Radionuclides
Interim Baseline Risk Assessment for the Sharon Steel/Midvale Tailings Site	N/A	N/A
Jefferson County Health Department	N/A	N/A
Last Chance Dam and Reservoir—Preliminary Feasibility Study	Soils	Metals
Rocky Flats Program Unit	N/A	N/A
Rocky Flats Reading Room	Surface Water	Radionuclides
Superfund Records Center	Surface Water/Sediment/Soils	metals
U.S. Army Corps of Engineers	Surface Water/Sediment	Metals/Radionuclides
U.S. Geological Survey Library	Sediment	Radionuclides
U.S. Geological Survey Water Resources Division	N/A	N/A
University of Colorado at Boulder	N/A	N/A
Water Quality Control Division—STORET (EPA, 1993DB and 1994DB)	Surface Water	Metals
Westminster Department of Water and Environmental Quality	N/A	N/A

N/A = No available data.

Originally, this data set was intended to provide background data for the OU 1 and OU 2 investigations. Because of variability in wind direction and possible inconsistencies with the soil composition at OU 3, there were questions concerning the appropriateness of the Rock Creek data set for background comparisons to OU 3 soil data. However, because of similar sampling methods to those used on OU 3, similar soil types, proximity, and availability, it was determined that the Rock Creek data were a representative background data set for quantitative comparison to OU 3 surface soil data.

The *Background Soils Characterization Project* (BSCP) was conducted in 1994 to determine regional background concentrations of radionuclides and other metals in surficial soils. Specifically, its objectives included augmenting the Rock Creek data set with samples collected in 1994, and comparing the BSCP data to the Rock Creek data to assess the validity of Rock Creek data as background for fallout radionuclides.

Results of the BSCP show that the Rock Creek data set is representative of background radionuclides, including all plutonium isotopes, americium, and uranium isotopes. Plutonium and americium are considered above background levels in OU 3 soils based on the comparison to the Rock Creek data, and are soil COCs for OU 3 based on the COC selection process. Therefore, any uncertainty associated with the Rock Creek americium-241 and plutonium-239, -240 data as a background data set is not relevant for OU 3.

4.2.2 Surface Water

The OU 3 reservoir surface-water data set was compared qualitatively against the stream surface-water data from (DOE, 1993a), which included 175 samples collected from February 1989 to December 1992 (Figure 4-2). No appropriate background data sets from the Background Geochemical Characterization Report were available for statistical comparison to reservoir water. OU 3 reservoir surface-water data and background stream surface-water data were also compared qualitatively because the data sets are similar in geologic setting and location, thereby justifying a qualitative comparison.

Both stream surface water and reservoir surface-water data were compared qualitatively to literature values. The OU 3 stream-water data set had an insufficient number of data points for a statistical comparison to background data. The primary data sets identified during the benchmark data collection activities for surfacewater include Ralston Creek, Croke Canal, and Farmer's Highline Canal (Arvada, 1994 [TM 4]). These streams are near Rocky Flats, with some feeding Standley Lake. OU 3 reservoir surface water data were compared to other water bodies along the Front Range including Chatfield Reservoir, Cherry Creek Reservoir, Bear Creek Lake, and Harriman Lake (Arvada, 1994; EPA, 1993, 1994a). Literature values were available for antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc.

The creek data obtained from the literature came from the Arvada Department of Water and Environmental Quality database. The reservoir data were obtained from EPA's STORET database, which contains water quality information from 1970 through 1993.

4.2.3 Sediment

A comparable background data set for reservoir sediment was not available for statistical comparison tests. Consequently, the reservoir sediment data were compared qualitatively to the sixty-six stream sediment samples from the Background Geochemical Characterization Report (Figure 4-2). A qualitative comparison was also performed between OU 3 reservoir sediment data and benchmark data.

The benchmark data that were used for reservoir surface and subsurface sediment comparisons include four lakes in Rocky Mountain National Park: Lake Husted, Lake Louise, Lake Haiyaha, and the Loch (Heit et al., 1984); Halligan Reservoir and Wellington Lake (Cohen et al., 1990); Cherry Creek Reservoir (DRCOG, 1989) data in USGS open file reports; and Marston Lake and Ralston Reservoir (DOE, 1991c).

4.2.4 Groundwater

Two groundwater monitoring wells were installed during the OU 3 field investigation. One well was installed downstream of the Great Western Reservoir dam and the second well was installed downstream of the Standley Lake dam. Both wells were installed to evaluate the potential for contaminants to migrate from the surface-water bodies to shallow groundwater. Because the OU 3 data set has an insufficient number of wells for quantitative statistical comparison to background, the groundwater data for the UHSU and LHSU in the Background Geochemical Characterization Report (DOE, 1993a) have been used in a qualitative comparison to the OU 3 data set. Data for Well 49192 (Great Western Reservoir—IHSS 200) have been compared to the background data for the UHSU, and data for Well 49292 (Standley Lake—IHSS 201) have been compared to the background data for the LHSU.

4.3 SOIL EVALUATIONS

The nature and extent of contamination evaluations for soils include surface soils followed by subsurface soils. The data evaluations include a comparison to background soil/data, a discussion of summary statistics, and a spatial analysis for radionuclides.

4.3.1 Surface Soils

The data sets used to evaluate the nature and extent of soil contamination in OU 3 consist of the RFI/RI surface soil data, 1991 Remedy Lands soil data, and background data for surface soils in the Rock Creek area (DOE, 1993b). The OU 3 RFI/RI surface soil data set consists of analytical results for 144 samples collected from 61, 10-acre plots between June 1992 and June 1993. As discussed previously in Section 2.2, each 10-acre plot was sampled by two methods (Rocky Flats and CDPHE). The results from these methods were averaged for use in the OU 3 database because there was not a statistical difference between results of the two methods. The 1991 Remedy Lands data consist of analytical results for 47 surface soil samples collected from the tilled and untilled strips of land formerly known as the Jefferson County Remedy Lands.

The purpose of the RFI/RI surface soil sampling was to evaluate the presence, activities, and distribution of radionuclides in surface soil. Soils were analyzed for radionuclides only (plutonium-239, -240, americium-241, uranium-233, -234, uranium-235, uranium-238). Metals were not analyzed for in soil samples because no source for a metals release from Rocky Flats to OU 3 via the air pathway has been identified. Historical soil sampling results for beryllium, one of the metals included on the Phase I Health Studies list of site-related analytes (CDPHE, 1992), indicates that beryllium was not detected above the analytical method detection limits and therefore, was not transported via the air pathway to the OU 3 soils.

In addition, a study of metals concentrations in OU 2, located upwind of OU 3, was conducted and included an evaluation of the potential for airborne transport of metals from OU 2 to OU 3 (Litaor, 1995, Appendix M). The assumption for this study was that if metals in OU 2 soils did not show patterns of airborne deposition, airborne deposition of metals in OU 3 would not be expected. The metals evaluated for this study included arsenic, beryllium, cadmium, chromium, lead, mercury, and nickel. Results of the analysis indicated that none of the metals analyzed for show evidence of airborne deposition in OU 2 and therefore, analysis of metals in OU 3 soils was not warranted.

The Remedy Lands (approximately 350 acres) is an area within OU 3 that has been recognized as exhibiting elevated plutonium-239, -240 activity in surface soils. In 1991, forty-seven surface soil samples were collected in an effort to verify previous sampling results and characterize the Remedy Lands area. These data have been commonly referred to as the "Jefferson County Data" and are included as OU 3 data for the background statistical comparison tests and the evaluations of nature and extent of contamination. The Remedy Lands soil samples were analyzed for plutonium-239, -240, plutonium-238, and americium-241. The Remedy Lands acreage was acquired by the City of Westminster from Jefferson County in February 1995. Analysis of the surficial soil data indicates that plutonium-239, -240, and americium-241 are COCs to be evaluated further in the human health risk assessment. These chemicals were selected using the process described above in detail in TM4 (DOE, 1994d).

Data Summary

Summary statistics for the RFI/RI surface soil samples (after application of the data protocols) are presented in Appendix D. These tables show the summary statistics for each radionuclide analyzed in IHSS 199, including number of samples, minimum detected value, maximum detected value, arithmetic mean, geometric standard deviation, and 95 percent upper confidence limits (UCL). Data evaluation protocols for Rocky Flats state that all radionuclides must be treated as detected values in all quantitative data-analysis tasks (see Appendix F).

Based on the Rock Creek background soil sample results, the upper-bound background value (mean plus two standard deviations) for americium-241 and plutonium-239, -240 in soils are 0.04 pCi/g and 0.09 pCi/g, respectively. Nineteen out of the 61 soil plot samples and all 47 of the Remedy Lands samples have either americium-241 or plutonium-239, -240 activities that exceed the upper-bound background values. The sample locations that exceed the upper-bound background for americium-241 or plutonium-239, -240 are presented in Figures 4-3 and 4-4. The maximum americium-241 activity was detected in soil sample plot PT14192 (0.52 pCi/g), located east of the Rocky Flats eastern boundary. The maximum plutonium-239, -240 activity was detected within the Remedy Lands at sample location U1A (see Figures 4-4, 4-5A) (6.468 pCi/g). Results of the OU 3 RI soils sampling data are presented in Figure 4-5B. The arithmetic mean for americium-241 and plutonium-239, -240 in all surface soil samples was 0.035 pCi/g and 0.158 pCi/g, respectively. The geometric mean for americium-241 and plutonium-239, -240 was 0.017 pCi/g, and 0.057 pCi/g, respectively.

Spatial Distribution of Plutonium in Surface Soils

A comprehensive study of plutonium contamination in soils was performed to assess the spatial distribution of plutonium-239, -240 in the vicinity of Rocky Flats.

The main goal of the study was to provide a complete appraisal of the spatial extent of plutonium-239, -240 in the soils around Rocky Flats. The objectives of the study were as follows:

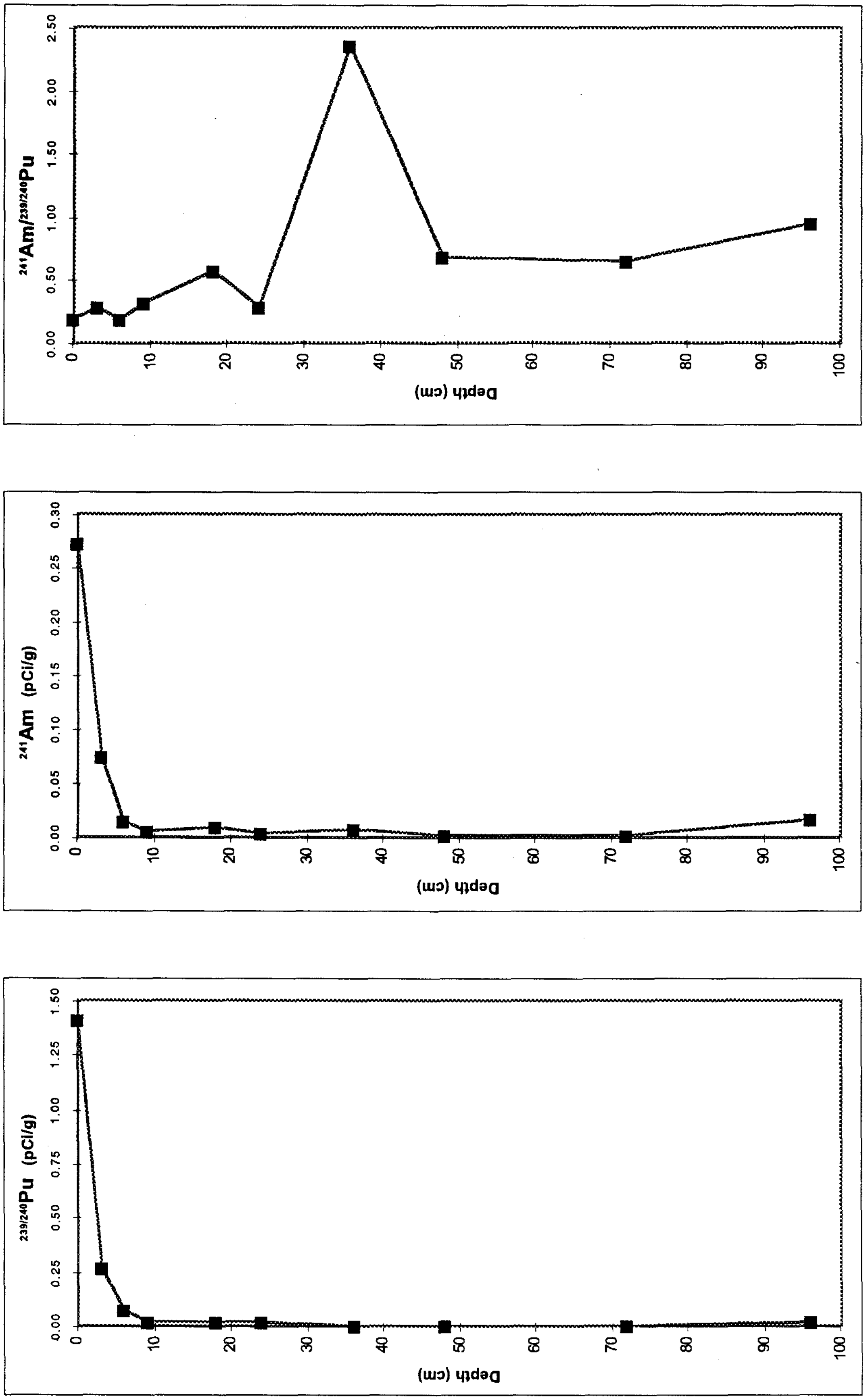
- Assess the spatial distribution of plutonium-239, -240 in soils around Rocky Flats using geostatistical techniques
- Assess the degree of uncertainty in the spatial estimation of plutonium-239, -240

The results of this study can be found in Appendix M, Litaor et al. (1995). The technique of nonparametric indicator kriging was used to model distributions of plutonium-239, -240 in soils. An exhaustive data set was compiled for the study, which included data from current and historical sampling programs at Rocky Flats and OU 3. The distribution of plutonium activities resulting from this study is consistent with the hypothesis that plutonium-239, -240 and americium -241 predominantly dispersed from Rocky Flats by westerly winds (see Figures 4-6A, 4-6B). Highest activities are seen near the former 903 Pad drum storage area at Rocky Flats. Activities decline rapidly toward the eastern boundary of Rocky Flats and in OU 3. The kriging results were also used to construct "probability of exceedance" maps for plutonium-239, -240 in soils. Figures 4-7A and 4-7B present the "probability of exceedance" of the programmatic preliminary remediation goal (PPRG) for residential occupancy as the threshold value for plutonium (3.43 pCi/g) and americium (2.37 pCi/g), respectively. Only probabilities greater than 20 percent are illustrated on the two figures. The isocontour lines are presented in areas where the probability is greater than 20 percent that the plutonium-239, -240 and americium-241 activities in soil in these areas will exceed 3.43 and 2.37 pCi/g, respectively. All areas of OU 3, except the area in the vicinity of the Remedy Lands, have probabilities less than 20 percent that the PPRG for plutonium-239, -240 and americium-241 in soil will be exceeded. These results are consistent with results presented in the HHRA (Appendix A).

This study is significant in that it provides the most conclusive definition of offsite plutonium contamination to date. It not only considers the largest data set ever assembled for this type of evaluation, but it also provides estimates of uncertainty inherent in the interpolation of this data, By using an exhaustive data set, Litaor et al. (1995), was able to refine the work of other investigators and provide a more clear definition of the nature and extent of soil contamination in OU 3. The results of this evaluation suggest that the boundaries of OU 3 and IHSS 199 can be limited to a relatively small area east of the east gate of Rocky Flats.

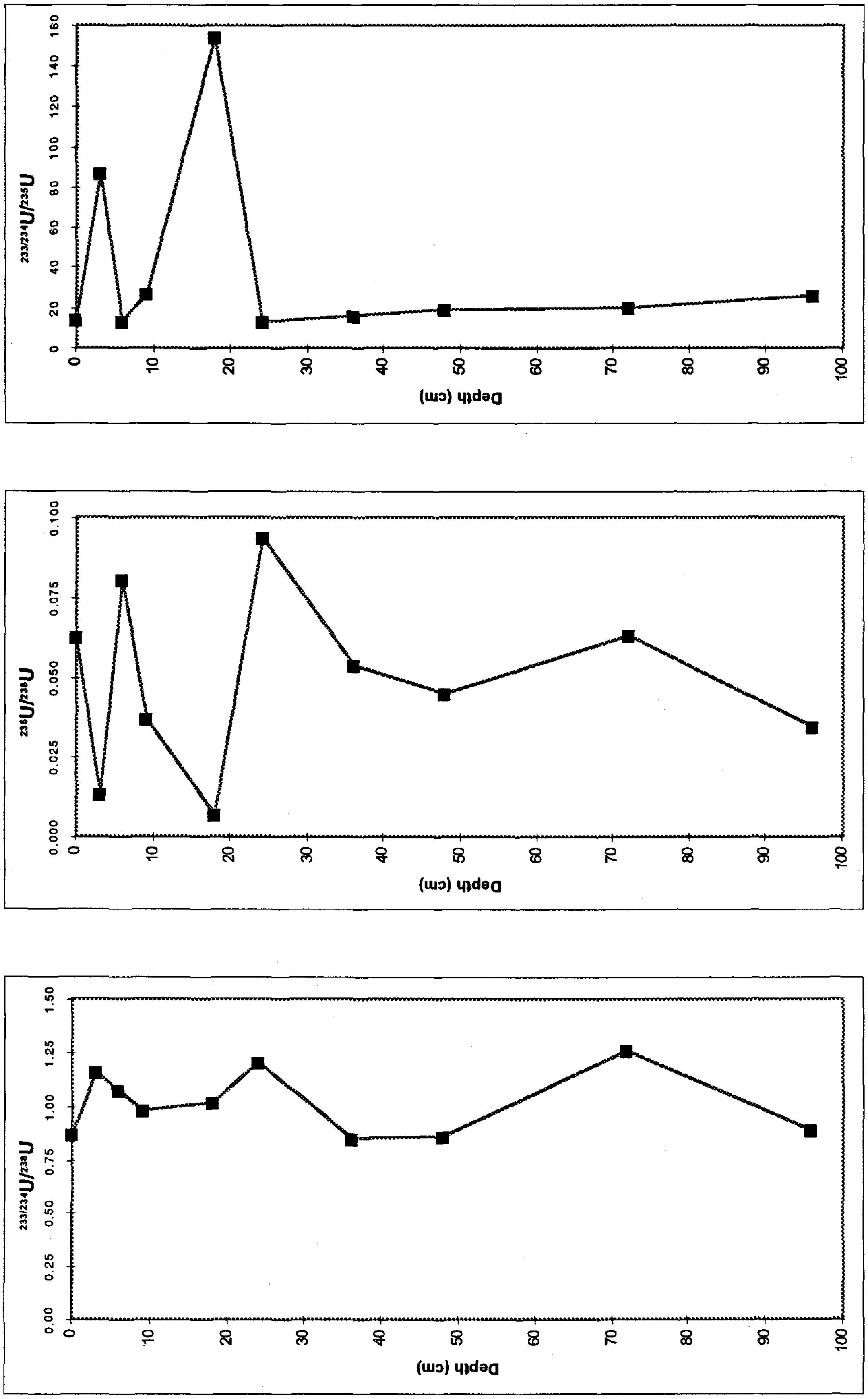
Many of the previous investigations of offsite contamination suffered from either limited data sets, or insufficient quantification of their interpolation error. Krey and Hardy (1970) sampled 33 sites located as far a 64 km east, south and north of Rocky Flats, to establish a plutonium-239, -240 iso-contour map around the Rocky Flats site (Figure 1, Litaor et al. 1995). The limited number of data points required a significant amount of extrapolation over large unsampled areas and relied heavily on a few individual data points (Litaor, et al., 1995). Seed et al. (1971) produced an isopleth map using data from 135 soil samples. This map differed significantly from the previous contour map of Krey and Hardy (1970), especially in the magnitude and extent of plutonium-239, -240 activity in the offsite soils. A second isopleth map was constructed by Krey (1976) that showed the ratio of Rocky Flats related plutonium to global fallout. This map was constructed using 22 data points and extended contours southeastward into southeast Denver. Johnson (1981) used this information to develop a cancer incidence assessment for the Denver area (Figure 1, Litaor et al., 1995). Here again, the assessment was made with little data, no analysis of the uncertainty, and significant extrapolation over large unsampled areas.

In refining the extent of plutonium contamination from Rocky Flats, Litaor et al. (1995) also eliminated the southeastern component of contaminant plumes mapped by other workers (Krey and Hardy, 1970; Seed et al., Krey, 1976). Two samples that were taken along the southeast drainages leading away from the site exhibited plutonium-239, -240 levels that were significantly higher that surrounding data points. E-type estimate surfaces developed by Litaor et al. (1995) did not predict a southeast plume. The source of the higher values for plutonium activity in the southeast direction is somewhat unclear. A possible mechanism is sediment transport along local drainages. Johnson et al. (1976) showed that sediment samples taken from the Woman Creek drainage system approximately 2 km east of Indiana Street exhibited plutonium-239, -240 levels 3 to 67 times greater than soil samples taken outside the flood



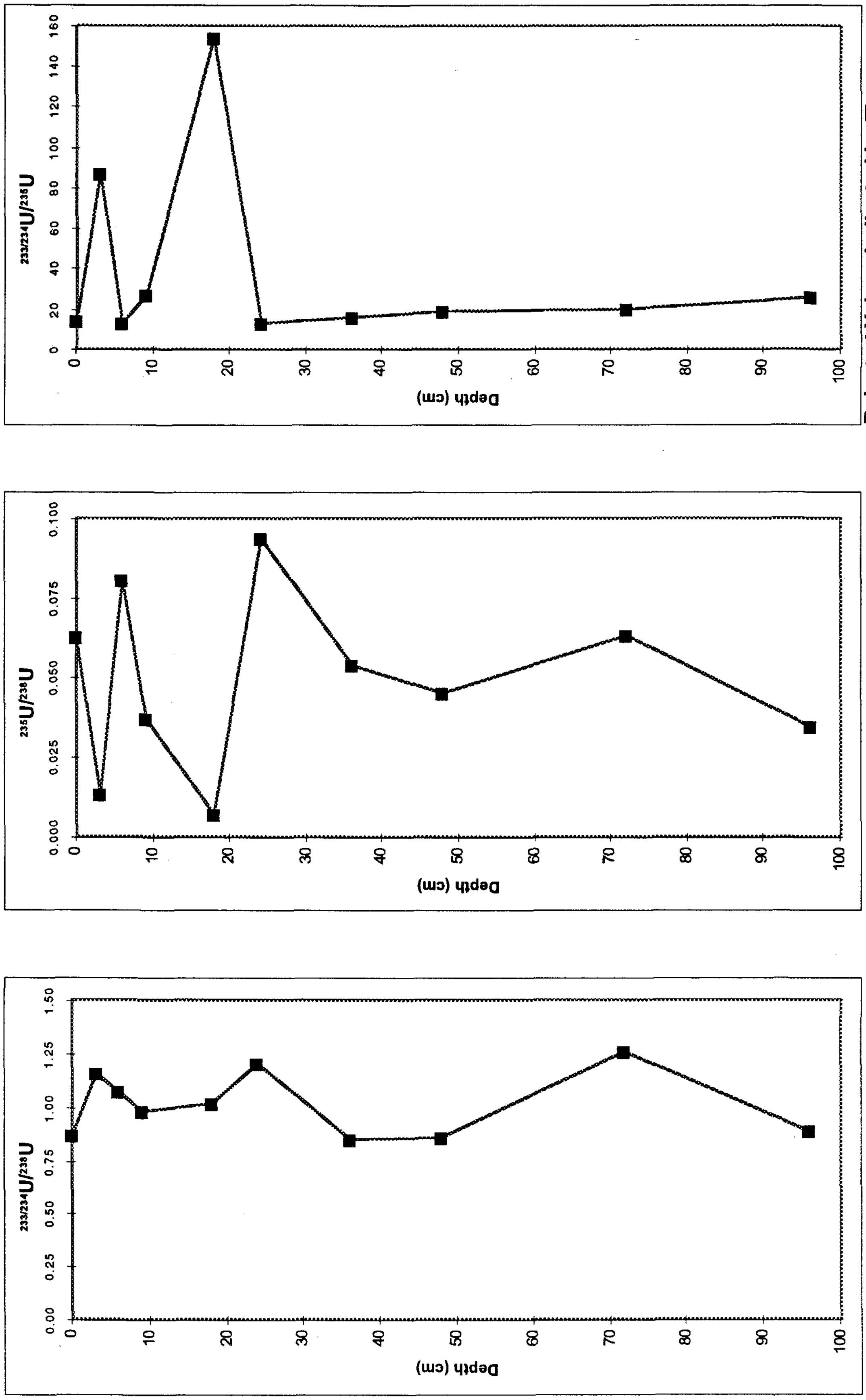
Rejected Values Indicated by □

Figure 4-8 Trench Profile for TR02792



Rejected Values Indicated by □

Figure 4-8 Trench Profile for TR02792



Rejected Values Indicated by ☐

Figure 4-8 Trench Profile for TR02792

plains. This finding strongly supports the interpretation that plutonium-239, -240 dispersion in the environment was facilitated by dominantly eolian processes, with some sediment concentration and transport along drainages (Litaor et al., 1995).

Summary of Surface Soils

Based on the background comparison and the COC selection process, plutonium-239, -240 and americium-241 are elevated above background levels and are considered COCs. The highest levels of plutonium-239, -240 and americium-241 are located east of Indiana Street in the Remedy Land area. Contaminants are defined as a west to east trending plume with plutonium and americium levels decreasing to background levels within 2 to 3 miles of the Rocky Flats east gate.

4.3.2 Subsurface Soils

Eleven trenches were excavated and sampled in the subsurface soils of OU 3 (Figure 2-1). The purpose of the sampling was to evaluate the presence, vertical distribution, and activities of radionuclides in subsurface soils. In each trench, 10 samples were collected from the 0 to 96 cm depth interval and were analyzed for plutonium-239, -240, americium-241, uranium-233, -234, uranium-235, and uranium-238 contamination. The highest activities of americium-241 were detected in trench locations TR02792 (0.2723 pCi/g), TR03492 (0.1441 pCi/g), and TR03692 (0.1276 pCi/g). The highest plutonium-239,-240 activities were observed from 0 to 3 cm in trench locations TR03492 (1.593 pCi/g) and TR02792 (1.412 pCi/g).

Trench soil summary statistics for radionuclides in IHSS 199 are presented in Appendix D. These statistics are based on data that were classified as acceptable by the independent data validators (i.e., 347 of 549 samples). Accompanying each radionuclide in the table is the number of samples, minimum and maximum detected values, arithmetic and geometric mean, geometric standard deviation, and 95 percent UCL.

Maximum contamination of plutonium-239, -240 and americium-241 were found at the surface of the trenches (0 to 3 cm) and decreased rapidly with depth to less than 0.01 pCi/g for americium-241 and 0.10 pCi/g for plutonium-239, -240 at a depth of approximately 10 cm. This indicates that the presence of these analytes in OU 3 soils is a result of windblown deposition. Evidence of plutonium-239, -240 and americium-241 elevated above background levels is found only in surface soils. Concentrations of americium and plutonium in the subsurface soil below 10 cm (ranging from slightly above detectable levels for both analytes to 0.02 pCi/g, and 0.1 pCi/g, respectively) are similar to upper-bound background levels (0.04 and0.09 pCi/g, respectively). The arithmetic and geometric means for plutonium-239, -240 and americium-241 in subsurface soils below 10 cm (0.005 pCi/g and 0.01 pCi/g, respectively) were substantially lower than background levels.

Subsurface soils were also evaluated using the statistical tests described in TM 4. The results of these tests show that americium-241 and plutonium-239, -240 are present in subsurface soils at elevated levels compared to background levels. This can be attributed to americium-241 and plutonium-239,-240 activities in the surface portions (0 to 3 cm) of the trenches. As stated earlier, their concentration in subsurface soils (i.e., below 10 cm) is very low. As such, the indicated elevated levels of americium-241 and plutonium-239, -240 in subsurface soils is based primarily on the activities observed in the surface portions of the trenches. Therefore, there were no COCs selected for the subsurface soils.

An illustration of how radionuclides vary with depth for trench TR02792, located south and east of Great

Western Reservoir, is presented in Figures 4-8 and 4-9. Figure 4-8 shows how americium-241 and plutonium-239, -240 have the highest activities from 0 to 3 cm and significantly lower, more constant activities from 10 to 96 cm (representing background conditions). Figure 4-9 shows the natural variation of the uranium isotopes with depth. Radionuclide activity profiles for all trenches are provided in Appendix H.

The highest activities for the uranium isotopes in the subsurface soil samples were found in the area of the southern parcel of the Remedy Lands (2.02 pCi/g for uranium-233, -234, 0.36 pCi/g for uranium-235, and 2.15 pCi/g for uranium-238). The highest activities for plutonium and americium in the trenches (1.59 pCi/g and 0.27 pCi/g, respectively) were observed in the same areas as for the surface soils.

Statistical comparisons of uranium activities in OU 3 subsurface soil to background soil show significant differences in only one test, the UTL test. This comparison showed the majority of the trench samples contained uranium activities below the UTLs. Only four samples in two of the trenches were in exceedance. Trench TR03492, located in the southern parcel of the Remedy Lands, surpassed the UTL of uranium-235 only. The concentration of uranium-235 was 0.26 pCi/g (UTL = 0.199). Trench TR03692 had elevated levels of uranium-233, -234, uranium-235, and uranium-238. Concentrations for uranium-233, -234, uranium-235, and uranium-238 were 2.02 pCi/g (UTL = 1.86 pCi/g), 0.36 pCi/g (UTL = 0.199 pCi/g), and 2.15 pCi/g (UTL = 2.00 pCi/g), respectively. Trench TR03692 is located just north of the southern parcel of the Remedy Lands and west of Mower Reservoir (Figure 2-1). All other statistical tests indicated there were no statistical differences between the OU 3 subsurface soil data and background soil data for uranium.

Sampling for selected physical parameters was conducted by soil horizons rather than by the incremental depth procedure. Appendix H presents a summary of the physical parameters analyzed including mineralogy, particle size, bulk density, specific surface area, and ion exchange capacity of the soils. The majority of soil horizons contained quartz and clay fractions consisting of a mixture of smectite, illite, and kaolinite. In all horizons, smectite was the dominant clay mineral; typically accounting for about 60 percent of the clay. Smectite in these soils may be derived partly from Cretaceous-age shale, which formed the parent material for many of the soils investigated, either directly or as a source of the colluvium or alluvium in which the soils developed. Smectite commonly occurs in fine clay fractions, a size that makes smectite particles susceptible both to transport by wind and water erosion and to accumulation in low-lying landscape positions.

With a few exceptions, mica content in the clays was greatest near the surface and decreased with depth. This is the opposite trend from what is expected in moderately to highly weathered soils, and it confirms the hypothesis that the soils have not significantly weathered since deposition of the parent materials.

The soils were described according to guidelines established by the Soil Survey Staff (1975, 1981), and classified as Aridic Argiustoll (TR02792, TR03192), Typic Argiaquoll (TR02892), Pachic Argiustoll (TR03292, TR03392, TR03792), Aridic Haplustoll (TR02992), Fluvaquentic Endoaquoll (TR03092), Torrertic Argiustoll (TR03492), Torrifluventic Haplustoll (TR03592),and Pachic Calcuistoll (TR03692). Most of the soils in this study were Argiustolls (i.e., soils formed in a semi-arid climate under the influence of prairie vegetation and containing subsurface accumulations of clay). All of the soils exhibited relatively thick surficial horizons with abundant organic matter. This type of soil horizon reflects annual belowground additions of organic matter to the soil by decomposition of the roots of prairie grasses and forbs.

Over 96 percent of plutonium-239, -240 activities, and 93 percent of americium-241 activities in the subsurface soils were accounted for in the top 12 cm of the soil. This distribution strongly suggests that little downward movement of plutonium and americium has occurred within these soils during the last 25 years (Litaor, 1995; Appendix M).

Summary of Subsurface Soils

Based on the background comparison, americium-241 and plutonium-239, -240 activities are above background from 0 to 6 cm in some of the trenches. Below 10 cm, activities of americium and plutonium are the same as background levels. These data suggest that little, if any, vertical migration is occurring. Patterns of activities for these two analytes in the trench profiles suggest wind-blown contamination from Rocky Flats as the source for americium-241 and plutonium-239, -240 in OU 3 surface soils. Americium-241 and plutonium-239, -240 have been identified as COCs in surface soils for the HHRA.

Activities of uranium isotopes in OU 3 subsurface soils were similar to background levels. In addition, patterns of activities for uranium appear to represent natural variability rather than wind-blown contamination from Rocky Flats. Uranium isotopes were not identified as COCs in soils for the HHRA.

4.4 SURFACE WATER EVALUATION

The surface water investigation consisted of the sampling and analysis of water from the creeks/drainages (Walnut Creek, Woman Creek, Dry Creek Valley Ditch, Church Ditch, Coal Creek, and Big Dry Creek) and reservoirs (Standley Lake, Great Western Reservoir, and Mower Reservoir) in OU 3. A total of 52 surface water samples (excluding quality-control samples) were collected from 33 sample locations (Figure 2-2). The purpose of the surface water sampling and subsequent chemical analysis was to characterize radionuclides and metals contained within the creeks/drainages and reservoirs in OU 3. The surface water samples were analyzed for dissolved and total radionuclides, dissolved and total metals, pesticides, and water-quality parameters. Volatile organic compounds were analyzed only at Mower Reservoir (IHSS 202). In addition, several samples in Great Western Reservoir (IHSS 200) were analyzed for various tripesticides (10 pesticides, including atrazine and simazine).

Four stream samples were collected in the Great Western Reservoir (IHSS 200) drainage, and four stream samples were collected in the Standley Lake (IHSS 201) drainage during June to October 1992. No stream surface samples were available during the sampling period for the Mower Reservoir (IHSS 202) drainage due to a lack of available water. Only eight total metal/radionuclide samples and three dissolved metal/radionuclide samples were collected for all IHSSs. Water quality analyses were also performed on stream surface water samples.

The OU 3 reservoir surface water data set consists of 15 samples in Great Western Reservoir (IHSS 200), fourteen samples in Standley Lake (IHSS 201), and thirteen samples in Mower Reservoir (IHSS 202). These samples were collected from July to October 1992.

Analyses indicate that concentrations of total constituents (unfiltered) are greater than the corresponding (filtered) dissolved constituents because total analysis include both the suspended and dissolved fraction of the analyte measured. Based on a comparison of the total versus dissolved analytical results on a sample-by-sample comparison, 6 percent of the analysis were greater for the dissolved fraction than the corresponding total fraction. In the instances where the dissolved fractions were greater, the dissolved results were only slightly greater than the total. The analytes with the greatest number of occurrences, where dissolved concentrations exceeded total concentrations, were for the major ions: calcium, magnesium, potassium, silicon, and sodium. From an exposure perspective, the total analysis are most useful because incidental exposure to surface water during recreational use of the reservoirs would most likely involve unfiltered water. Because over 90 percent of the analysis indicated that the total fractions were greater than the dissolved fractions and the total analysis relate to exposure, only the total results are presented in this subsection.

Summary statistics for dissolved and total surface water samples (after application of the data protocols and before the COC selection process is applied) are presented in Appendix D. These tables show the summary statistics for each analyte analyzed in IHSSs 200, 201, and 202, including number of samples, detection frequency, minimum nondetected value, maximum nondetected value, minimum detected value, maximum detected value, arithmetic mean, standard deviation, and coefficient of variation. In addition, background and benchmark data for surface water are included in Appendix D.

4.4.1 Data Summary

Results of the background/benchmark comparison for all analytes in surface water are summarized in Table 4-4. The concentrations/activities of radionuclides and other metals detected in the OU 3 surface water are within background levels. Based on the comparison between the OU 3 data and the background and benchmark data, none of these analytes significantly exceed background levels. Volatile organic compounds were analyzed for in Mower Reservoir only and were not detected. Tripesticides, including atrazine and simazine were also not detected in any of the surface water. In addition, all surface water analytes were evaluated by the COC selection process. The results of this evaluation indicated that there were no COCs requiring further evaluation for the human health risk assessment in the surface water in OU 3. A detailed discussion of the COC selection process can be found in TM 4 (DOE, 1994d). The background/benchmark comparison for radionuclides is presented in the following subsection.

Radionuclides

Based on the background comparison between OU 3 surface water samples (DOE, 1993a) and the surface water samples presented in the Background Geochemical Characterization Report, americium-241 activities in all three reservoirs were less than the upper-bound background (i.e., mean plus two standard deviations) and maximum values from the background data. The OU 3 reservoir surface water data were also below the benchmark literature values (Appendix D). The mean americium-241 activities in Great Western Reservoir, Standley Lake, and Mower Reservoir, were 0.005, 0.006, and 0.006 pCi/l, respectively. The maximum activity of americium-241 (0.026 pCi/l) was detected at location SW00392 in Standley Lake (see Figure 2-2).

The OU 3 surface water data for plutonium-239, -240 in Great Western Reservoir and Standley Lake were less than both the mean and maximum background data. In Mower Reservoir, the surface water data were less than the upper-bound background value and less than the maximum background values. All OU 3 reservoir data were less than the reported mean and maximum benchmark values. The mean plutonium-239, -240 activities for Great Western Reservoir, Standley Lake, and Mower Reservoir, were 0.002, 0.002, and 0.005 pCi/l, respectively. The maximum plutonium-239, -240 activity (0.03 pCi/l) was detected in Mower Reservoir at location SW03592.

With the exception of uranium-235 in Great Western Reservoir, the mean and maximum activities for the uranium isotopes in all three reservoirs were less than the upper-bound background value (mean plus two standard deviations) and less that the maximum background values. One sample (SW07107CH) at location SW01692 exceeded the background uranium-235 maximum value (0.41 pCi/l versus a background maximum of 0.376 pCi/l).

Table 4-4
Background/Benchmark Comparison Results OU 3
OU 3 Surface Water

1 IHSS	2 Parameter[a]	3 BGCR Evaluation	4 Benchmark Evaluation
200	Aluminum	<MEAN + 2SD, MAX	>MEAN,MAX
201	Aluminum	<MEAN,MAX	<MEAN,MAX
202	Aluminum	<MEAN, MAX	<MEAN,MAX
200	Americium-241	<MEAN + 2SD, MAX	<MEAN,MAX
201	Americium-241	<MEAN + 2SD, MAX	<MEAN,MAX
202	Americium-241	<MEAN + 2SD, MAX	<MEAN,MAX
200	Antimony	ND	ND
201	Antimony	ND	ND
202	Antimony	ND	ND
200	Arsenic	MEAN,MAX	<MAX
201	Arsenic	ND	ND
202	Arsenic	~MEAN + 2SD,>MAX	<MAX
200	Barium	<MEAN,MAX	<MEAN,MAX
201	Barium	<MEAN,MAX	<MEAN,MAX
202	Barium	<MEAN,MAX	<MEAN,MAX
200	Beryllium	<MEAN,MAX	NA
201	Beryllium	<MEAN,MAX	NA
202	Beryllium	ND	ND
200	Cadmium	<MEAN.MAX	<MAX
201	Cadmium	<MEAN,MAX	<MAX
202	Cadmium	<MEAN,>MAX	>MAX
200	Calcium	<MEAN,MAX	<MEAN,MAX
201	Calcium	<MEAN,MAX	<MEAN,MAX
202	Calcium	<MEAN,MAX	<MEAN,MAX
200	Cesium	<MEAN,MAX	NA
201	Cesium	ND	ND
202	Cesium	<MEAN,MAX	NA
200	Chromium	<MEAN,MAX	<MEAN,MAX
201	Chromium	<MEAN,MAX	<MEAN,MAX
202	Chromium	<MEAN + 2SD,>MAX	>MEAN,MAX
200	Cobalt	<MEAN,MAX	>MEAN,<MAX
201	Cobalt	<MEAN,MAX	<MEAN,MAX
202	Cobalt	ND	ND
200	Copper	<MEAN + 2SD,>MAX	<MAX
201	Copper	<MEAN + 2SD,>MAX	<MAX
202	Copper	<MEAN,MAX	<MAX
200	Cyanide	ND	ND
201	Cyanide	<MEAN + 2SD,>MAX	NA
202	Cyanide	ND	ND
200	Iron	<MEAN,MAX	>MEAN,MAX
201	Iron	<MEAN,MAX	<MEAN,MAX
202	Iron	<MEAN,MAX	<MEAN,MAX
200	Lead	<MEAN + 2SD,<MAX	<MEAN,MAX
201	Lead	<MEAN + 2SD,MAX	<MEAN.MAX
202	Lead	>MEAN + 2SD,MAX	<MEAN,MAX
200	Lithium	<MEAN,MAX	>MEAN,MAX
201	Lithium	<MEAN,MAX	>MEAN,MAX
202	Lithium	<MEAN,MAX	>MEAN,MAX
200	Magnesium	<MEAN,MAX	<MEAN,MAX
201	Magnesium	<MEAN + 2SD,MAX	<MEAN,MAX
202	Magnesium	<MEAN + 2SD,MAX	<MEAN,MAX

Table 4-4 (continued)

1 IHSS	2 Parameter[a]	3 BGCR Evaluation	4 Benchmark Evaluation
200	Manganese	<MEAN,MAX	<MEAN,MAX
201	Manganese	<MEAN + 2SD,<MAX	<MEAN,>MAX
202	Manganese	<MEAN,MAX	<MEAN,MAX
200	Mercury	ND	ND
201	Mercury	<MEAN,MAX	<MEAN,MAX
202	Mercury	<MEAN,MAX	<MEAN,MAX
200	Molybdenum	<MEAN,MAX	<MEAN,MAX
201	Molybdenum	<MEAN,MAX	<MEAN,MAX
202	Molybdenum	<MEAN,MAX	<MEAN,MAX
200	Nickel	<MEAN,MAX	<MEAN,MAX
201	Nickel	<MEAN,>MAX	<MEAN,>MAX
202	Nickel	<MEAN,>MAX	<MEAN,MAX
200	Plutonium-239 -240	<MEAN,MAX	<MEAN,MAX
201	Plutonium-239 -240	<MEAN,MAX	<MEAN,MAX
202	Plutonium-239 -240	<MEAN + 2SD,MAX	<MEAN,MAX
200	Potassium	<MEAN + 2SD,MAX	<MEAN,MAX
201	Potassium	<MEAN + 2SD,MAX	<MEAN,MAX
202	Potassium	<MEAN,MAX	<MEAN,MAX
200	Selenium	ND	ND
201	Selenium	<MEAN + 2SD,MAX	MAX
202	Selenium	ND	ND
200	Silicon	<MEAN,MAX	NA
201	Silicon	<MEAN.MAX	NA
202	Silicon	<MEAN,MAX	NA
200	Silver	ND	ND
201	Silver	ND	ND
202	Silver	ND	ND
200	Sodium	<MEAN,MAX	<MEAN,MAX
201	Sodium	>MEAN + 2SD, >MAX	<MEAN,MAX
202	Sodium	<MEAN + 2SD, >MAX	<MEAN,>MAX
200	Strontium	<MEAN,MAX	<MEAN,>MAX
201	Strontium	<MEAN,MAX	<MEAN,MAX
202	Strontium	<MEAN,MAX	<MEAN,MAX
200	Thallium	ND	ND
201	Thallium	ND	ND
202	Thallium	ND	ND
200	Tin	<MEAN,MAX	NA
201	Tin	ND	ND
202	Tin	<MEAN,MAX	NA
200	Tritium	<MEAN,MAX	<MEAN,MAX
200	Uranium-233, -234	<MEAN + 2SD,MAX	<MEAN,MAX
201	Uranium-233, -234	<MEAN + 2SD,MAX	<MEAN,MAX
202	Uranium-233, -234	<MEAN,MAX	<MEAN,MAX
200	Uranium-235	<MEAN + 2SD,>MAX	>MAX
201	Uranium-235	<MEAN + 2SD,MAX	>MAX
202	Uranium-235	<MEAN,MAX	>MAX
200	Uranium-238	<MEAN + 2SD,MAX	<MEAN,MAX
201	Uranium-238	<MEAN + 2SD,MAX	<MEAN,MAX
202	Uranium-238	<MEAN,MAX	<MEAN,MAX

Table 4-4 (Continued)

1 IHSS	2 Parameter[a]	3 BGCR Evaluation	4 Benchmark Evaluation
200	Vanadium	<MEAN,MAX	NA
201	Vanadium	<MEAN,MAX	NA
202	Vanadium	<MEAN,MAX	NA
200	Zinc	<MEAN + 2SD,<MAX	>MEAN,MAX
201	Zinc	<MEAN + 2SD,<MAX	>MEAN,MAX
202	Zinc	<MEAN + 2SD,<MAX	<MEAN,MAX

a Total Analysis

Notes:
IHSS - Individual Hazardous Substance Site.
ND = Not detected.
NA = No literature data available.

MAX = maximum value.
<MEAN = OU 3 mean value is less than background or benchmark mean value.
>MEAN = OU 3 mean value is greater than background or benchmark mean value.
<MEAN, MAX = OU 3 mean and maximum values are less than background or benchmark mean and maximum values.
>MEAN, MAX = OU 3 mean and maximum values are greater than background or benchmark mean and maximum values.
MEAN + 2SD = upper-bound background value (i.e., mean plus two standard deviations).
Column 3: Comparison of OU 3 stream to Background Geochemical Characterization Report stream data.
Column 4: Comparison of OU 3 reservoir to benchmark lake data.

Five surface water samples collected from Great Western Reservoir were analyzed for tritium. The tritium concentrations detected in all five samples were less than the background mean and maximum values for tritium data, and less than the reported benchmark data. Tritium activities ranged from below the analytical detection level to a maximum activity of 144 pCi/l. The mean tritium value was 47.8 pCi/l.

4.4.2 Summary of Surface-Water Results

Based on the background and benchmark comparisons, no surface-water analytes in OU 3 are considered to be significantly elevated over background levels. In addition, no COCs were identified for surface water in any of the reservoirs for the HHRA.

4.5 SEDIMENT EVALUATIONS

Sediment investigations consisted of sampling sediment located in creeks/drainages and reservoirs in OU 3. The purpose of the sampling was to evaluate the presence, concentrations, and distribution of potential contaminants. Sediment grab samples were collected to characterize the potential lateral extent of contamination in surficial sediments. Sediment core samples were collected to characterize the potential vertical extent of contamination in reservoir bottom sediments.

The sediment investigation consisted of the sampling and analysis of sediments from the creeks/drainages (Walnut Creek, Woman Creek, Dry Creek, Valley Ditch, Church Ditch, Coal Creek, and Big Dry Creek) and reservoirs (Standley Lake, Great Western Reservoir, and Mower Reservoir) in OU 3.

Summary statistics for OU 3 sediment samples (after application of the data protocols and before the COC selection process is applied) are presented in Appendix D. Summary statistics are presented separately for surface and subsurface sediment samples, and reservoir data are presented separately on the surface sediment tables. These tables show the summary statistics for each analyte analyzed in IHSSs 200, 201, and 202, including number of samples, detection frequency, minimum nondetected value, maximum nondetected value, minimum detected value, maximum detected value, arithmetic mean, standard deviation, and coefficient of variation. Background and benchmark data sets are also summarized in Appendix D.

4.5.1 Surface Sediment

A total of 128 surface sediment samples were collected from 104 sample locations (excluding quality control samples) during the 1983/1984 and the OU 3 RFI/RI investigations. (See Figures 2-3 through 2-5).

Data for sediment grab samples collected from OU 3 were analyzed for metals and radionuclides (gross alpha/beta, plutonium-239, -240, americium-241, uranium-233, -234, uranium-235, and uranium-238). VOCs were only analyzed for in Mower Reservoir (IHSS 202), and tritium was only analyzed for in Great Western Reservoir (IHSS 200). In addition, a portion of the sediment grab samples were analyzed for cesium-137 and strontium-89, -90.

The OU 3 surface sediment data were divided into two categories: stream and reservoir samples. The stream sediment data set comprises 8 samples from IHSS 200, 17 from IHSS 201, and 5 from IHSS 202. A total of 97 reservoir sediment samples were collected during the sampling period from May 1992 to November 1992. Thirty-six samples were collected from IHSS 200, 44 from IHSS 201, and 17 from IHSS 202.

Additionally, in 1983 and 1984, 114 reservoir sediment samples were collected from Great Western Reservoir and Standley Lake and analyzed for plutonium. The OU 3 Work Plan specified sampling points near these historical data locations for the purpose of comparability. A statistical comparison between the 1983/1984 sediment data and OU 3 data proved that the combination of the data would be appropriate for the OU 3 RFI/RI analysis (see memorandum in Appendix F). Based on this comparison, the plutonium results from the 1983/1984 sediment data were incorporated into the OU 3 reservoir sediment data set.

Data Summary for Stream Sediments

Table 4-5 summarizes the background and benchmark comparisons for all analytes in surface sediments. In addition, results of spatial and probability plot analysis are included. The concentrations/activities of radionuclides and other metals detected in the OU 3 stream sediments are within background levels. Based on the comparison between the OU 3 data and the background and benchmark data, none of these analytes significantly exceed background levels. Volatile organic compounds were analyzed for in and around Mower Reservoir and were not detected. In addition, all stream sediment analytes were evaluated by the COC selection process. The results of this evaluation indicated that there were no COCs requiring further evaluation for the human health risk assessment in the stream sediments of OU 3. A detailed

Table 4-5
Weight-of-Evidence Evaluation Summary
OU 3 Surface Sediments (Grab Samples)

1 IHSS	2 Chemical	3 Background Stream Evaluation	4 Benchmark Reservoir Evaluation	5 Spatial Trend?	6 PROBPLOT Analysis?	7 Comments
200	Americium-241	<MEAN,<MAX	NA	No Trend	NO	
201	Americium-241	<MEAN,<MAX	NA	No Trend	NO	
202	Americium-241	<MEAN,<MAX	NA	No Trend	NO	
200	Aluminum	<MEAN,<MAX	NA,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to BGCR and Lowry Landfill data, indicative of normal background population.
201	Aluminum	<MEAN,>MAX	NA,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to BGCR and Lowry Landfill data, indicative of normal background population.
202	Aluminum	<MEAN,<MAX	NA,<MAX	No Trend	YES	PROBPLOT: Two populations. Natural variability due to precipitation occurring with varying pH.
200	Antimony	<MEAN,<MAX	NA	No Trend	NO	
201	Antimony	<MEAN,<MAX	NA	No Trend	NO	
202	Antimony	<MEAN,<MAX	NA	No Trend	NO	
200	Arsenic	<MEAN+2SD,<MAX	<MEAN,>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
201	Arsenic	<MEAN,<MAX	<MEAN,>MAX	No Trend	YES	PROBPLOT: One population. Contribution of highly mineralized sediments from Clear Creek. Mean and maximum similar to benchmark data.
202	Arsenic	<MEAN+2SD,<MAX	<MEAN,>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to benchmark data, indicative of normal background population.
200	Barium	<MEAN,<MAX	NA,<MAX	No Trend	NO	
201	Barium	<MEAN,<MAX	NA,<MAX	No Trend	NO	
202	Barium	<MEAN,<MAX	NA,<MAX	No Trend	NO	
200	Beryllium	<MEAN,<MAX	<MEAN,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
201	Beryllium	<MEAN,<MAX	<MEAN,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Beryllium	<MEAN,<MAX	<MEAN,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
200	Cadmium	<MEAN,<MAX	>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.

Table 4-5 (continued)

1 IHSS	2 Chemical	3 Background Stream Evaluation	4 Benchmark Reservoir Evaluation	5 Spatial Trend?	6 PROBPLOT Analysis?	7 Comments
201	Cadmium	<MEAN+2SD,>MAX	>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Cadmium	ND	ND	ND	NO	ND
200	Calcium	<MEAN+2SD,>MAX	>MEAN	No Trend	NO	
201	Calcium	>MEAN+2SD,>MAX	>MEAN	No Trend	NO	
202	Calcium	>MEAN+2SD,>MAX	>MEAN	No Trend	NO	
200	Cesium	ND	NA	ND	NO	ND
201	Cesium	<MEAN,<MAX	NA	No Trend	NO	
202	Cesium	<MEAN,<MAX	NA	No Trend	NO	
200	Cesium-137	<MEAN,<MAX	NA	No Trend	NO	
201	Cesium-137	N/A	ND	ND	NO	
202	Cesium-137	N/A	N/A	No Trend	NO	
200	Chromium	<MEAN,<MAX	NA	No Trend	YES	PROBPLOT: Two populations. Small slopes for both populations due to adsorption or precipitation, organic adsorption, or algal bioaccumulation.
201	Chromium	<MEAN,>MAX	NA	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Chromium	<MEAN+2SD,<MAX	NA	No Trend	YES	PROBPLOT: Two populations. Small slopes for both populations due to adsorption or precipitation, organic adsorption, or algal bioaccumulation. Algal blooms and varying pHs were observed at Mower Reservoir.
200	Cobalt	<MEAN+2SD,>MAX	NA,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
201	Cobalt	<MEAN,<MAX	NA,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Cobalt	<MEAN,<MAX	NA,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
200	Copper	<MEAN+2SD,<MAX	NA,>MAX	No Trend	NO	
201	Copper	<MEAN+2SD,>MAX	NA,>MAX	No Trend	NO	
202	Copper	<MEAN,<MAX	NA,>MAX	No Trend	NO	
200	Cyanide	ND	ND	ND	NO	Not Detected
201	Cyanide	ND	ND	ND	NO	Not Detected
202	Cyanide	ND	ND	ND	NO	Not Detected

Table 4-5 (continued)

1 IHSS	2 Chemical	3 Background Stream Evaluation	4 Benchmark Reservoir Evaluation	5 Spatial Trend?	6 PROBPLOT Analysis?	7 Comments
200	Iron	>MEAN+2SD,>MAX	>MEAN,>MAX	No Trend	YES	PROBPLOT: One population. High iron concentrations typical for sediments from lacustrine environments. Means and medians for the three reservoirs are nearly the same.
201	Iron	<MEAN+2SD,<MAX	>MEAN,<MAX	No Trend	YES	PROBPLOT: One population. High iron concentrations typical for sediments from lacustrine environments. Means and medians for the three reservoirs are nearly the same.
202	Iron	<MEAN+2SD,<MAX	>MEAN,<MAX	No Trend	YES	PROBPLOT: One population. High iron concentrations typical for sediments from lacustrine environments. Means and medians for the three reservoirs are nearly the same.
200	Lead	<MEAN,<MAX	<MEAN,>MAX	No Trend	YES	PROBPLOT: One population. One sample exceeds 95 percentile concentration. Sample is located in deep portion of reservoir, rich in organic and fine grained material containing complex and adsorbed metals.
201	Lead	<MEAN+2SD,<MAX	>MEAN,>MAX	No Trend	YES	PROBPLOT: One population. Maximum concentration likely due to contribution from highly mineralized Clear Creek sediments.
202	Lead	<MEAN,<MAX	<MEAN,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
200	Lithium	<MEAN+2SD,<MAX	NA	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
201	Lithium	<MEAN+2SD,>MAX	NA	No Trend	YES	PROBPLOT: One population. Maximum concentration likely due to the fact that lithium is a common constituent in micas, which are released by acid attack, a phenomenon that happens in mine waste areas such as Clear Creek, a source feeding IHSS 201.
202	Lithium	<MEAN+2SD,<MAX	NA	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
200	Magnesium	<MEAN+2SD,<MAX	NA	No Trend	NO	
201	Magnesium	<MEAN+2SD,>MAX	NA	No Trend	NO	
202	Magnesium	<MEAN+2SD,<MAX	NA	No Trend	NO	

Table 4-5 (continued)

1 IHSS	2 Chemical	3 Background Stream Evaluation	4 Benchmark Reservoir Evaluation	5 Spatial Trend?	6 PROBPLOT Analysis?	7 Comments
200	Manganese	<MEAN+2SD,<MAX	NA,>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
201	Manganese	>MEAN+2SD,>MAX	NA,>MAX	No Trend	YES	PROBPLOT: One population. High manganese concentrations probably reflect contribution from the highly mineralized Clear Creek sediments to Standley Lake.
202	Manganese	<MEAN,<MAX	NA,>MAX	No Trend	YES	PROBPLOT: Two populations. Second population has a slope parallel to the lower population indicating a similar process forming both populations and the higher concentrations indicate an asymtotic character typical of the precipitation process.
200	Mercury	ND	<MEAN,>MAX	No Trend	NO	
201	Mercury	<MEAN,<MAX	>MEAN,>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Mercury	ND	>MEAN,>MAX	No Trend	NO	Means VERY similar to lake background. Insufficient number of detects to perform PROBPLOT.
200	Molybdenum	<MEAN+2SD,>MAX	NA,<MAX	No Trend	NO	
201	Molybdenum	<MEAN,<MAX	NA,<MAX	No Trend	NO	
202	Molybdenum	ND	ND	ND	NO	
200	Nickel	<MEAN+2SD,<MAX	<MEAN,<MAX	No Trend	YES	One sample exceeds 95th percentile concentration. This is the same location that has the highest conc. of Co, Mn and Fe. This is the result of Fe/Mn oxyhydroxide adsorption which elevates the Ni and Co concentrations through the adsorption process.
201	Nickel	<MEAN,<MAX	<MEAN,<MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Nickel	<MEAN,<MAX	<MEAN,>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
200	Potassium	<MEAN+2SD,<MAX	NA,<MAX	No Trend	NO	
201	Potassium	<MEAN+2SD,>MAX	NA,<MAX	No Trend	NO	
202	Potassium	<MEAN+2SD,<MAX	NA,<MAX	No Trend	NO	
200	Plutonium-238	N/A	N/A	N/A	NO	
201	Plutonium-238	N/A	N/A	N/A	NO	
202	Plutonium-238	N/A	N/A	N/A	NO	

Table 4-5 (continued)

1 IHSS	2 Chemical	3 Background Stream Evaluation	4 Benchmark Reservoir Evaluation	5 Spatial Trend?	6 PROBPLOT Analysis?	7 Comments
200	Plutonium-239, -240	<MEAN,<MAX	>MAX	No Trend	YES	PROBPLOT: One population. Mean similar to background and benchmark data, indicative of normal background population.
201	Plutonium-239, -240	<MEAN,<MAX	>MAX	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Plutonium-239, -240	<MEAN, <MAX	>MAX	No Trend	YES	PROBPLOT: One population.
200	Radium-226	<MEAN+2SD,<MAX	NA	No Trend	YES	One sample exceeds the 95th percentile value for background population. This sample is the same sample that exceeds 95th perc. for 233/234U, 235U, and 238U, suggesting natural uranium mineralization from the drainages rather than anthropogenic contamination.
201	Radium-226	N/A	NA	N/A	YES	Insufficient detections to represent a statistically definable population.
202	Radium-226	N/A	N/A	N/A	YES	Insufficient detections to represent a statistically definable population.
200	Radium-228	N/A	NA	No Trend	NO	
201	Radium-228	N/A	NA	N/A	NO	
202	Radium-228	N/A	N/A	N/A	NO	
200	Selenium	<MEAN+2SD,<MAX	<MEAN,>MAX	No Trend	NO	
201	Selenium	<MEAN+2SD,<MAX	<MEAN,>MAX	No Trend	NO	
202	Selenium	ND	<MEAN,>MAX	No Trend	NO	
200	Silicon	<MEAN+2SD,<MAX	NA	No Trend	YES	PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
201	Silicon	>MEAN+2SD,>MAX	NA	No Trend	YES	Max concentration less than 1% to an average crustal abundance of approx. 27%. Sediments in IHSS 201 have higher quartz content relative to mica content in each reservoir. Quartz is also readily available in mine waste near Clear Creek drainage.
202	Silicon	<MEAN+2SD,<MAX	NA	No Trend	NO	Insufficient data to perform PROBPLOT
200	Silver	<MEAN+2SD,>MAX	NA,>MAX	No Trend	NO	
201	Silver	<MEAN,<MAX	NA,>MAX	No Trend	NO	
202	Silver	<MEAN,<MAX	NA,>MAX	No Trend	NO	
200	Sodium	>MEAN+2SD,>MAX	NA	No Trend	NO	
201	Sodium	<MEAN+2SD,>MAX	NA	No Trend	NO	
202	Sodium	<MEAN+2SD,<MAX	NA	No Trend	NO	
200	Strontium-89/90	<MEAN+2SD,<MAX	NA	No Trend	NO	Creek: n=6, 0.01 off of background
201	Strontium-89/90	N/A	NA	N/A	NO	
202	Strontium-89/90	N/A	N/A	N/A	NO	

Table 4-5 (continued)

1 IHSS	2 Chemical	3 Background Stream Evaluation	4 Benchmark Reservoir Evaluation	5 Spatial Trend?	6 PROBPLOT Analysis?	7 Comments
200	Strontium	<MEAN+2SD,<MAX	NA,<MAX	No Trend	NO	
201	Strontium	<MEAN+2SD,<MAX	NA,>MAX	No Trend	NO	
202	Strontium	<MEAN+2SD,<MAX	NA,<MAX	No Trend	NO	
200	Thallium	ND	NA	ND	NO	Not Detected
201	Thallium	<MEAN,<MAX	NA	No Trend	NO	
202	Thallium	<MEAN,<MAX	NA	No Trend	NO	
200	Tin	ND	NA	ND	NO	Not Detected
201	Tin	ND	NA	ND	NO	Not Detected
202	Tin	ND	NA	ND	NO	Not Detected
200	Tritium	<MEAN+2SD,<MAX	NA	No Trend	NO	Creek: N=4, Detection Frequency = 50%
201	Tritium	<MEAN,<MAX	N/A	No Trend	NO	
202	Tritium	N/A	N/A	N/A	NO	
201	Uranium-233, -234	<MEAN,<MAX	<MAX	No Trend	YES	Reservoir: Total Uranium only. PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
202	Uranium-233, -234	<MEAN,>MAX	<MAX	No Trend	YES	Reservoir: Total Uranium only. PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
200	Uranium-233, -234	<MEAN,<MAX	<MAX	No Trend	YES	Reservoir: Total Uranium only. PROBPLOT: One population. Mean and Max similar to background and benchmark data, indicative of normal background population.
201	Uranium-235	<MEAN+2SD,>MAX	<MAX	No Trend	YES	Creek: BKGND MEAN & MAX > ONSITE MEAN & MAX BY 0.01, Reservoir: Total U only. PROBPLOT: One sample exceeds 95th percentile conc. This sample may represent a natural uranium mineralization from the drainages adjacent to the pediment.
202	Uranium-235	<MEAN+2SD,>MAX	<MAX	No Trend	YES	Creek: BKGND MAX > ONSITE MAX BY 0.01, Reservoir: Total Uranium only. Mean and maximum similar to benchmark data, indicative of normal background population.
200	Uranium-235	<MEAN+2SD,<MAX	<MAX	No Trend	YES	Reservoir: Total Uranium only. Mean and maximum similar to benchmark data, indicative of normal background population.
200	Uranium-238	=MEAN,<MAX	<MEAN	No Trend	NO	Reservoir: Total Uranium only
201	Uranium-238	<MEAN,>MAX	<MEAN	No Trend	NO	Reservoir: Total Uranium only
202	Uranium-238	<MEAN,<MAX	<MEAN	No Trend	NO	Creek: BKGND MAX > ONSITE MAX BY 0.08, Reservoir: Total Uranium only

Table 4-5 (continued)

1 IHSS	2 Chemical	3 Background Stream Evaluation	4 Benchmark Reservoir Evaluation	5 Spatial Trend?	6 PROBPLOT Analysis?	7 Comments
200	Vanadium	<MEAN+2SD,>MAX	<MEAN,<MAX	No Trend	NO	
201	Vanadium	<MEAN,<MAX	<MEAN,<MAX	No Trend	NO	
202	Vanadium	<MEAN+2SD,<MAX	<MEAN,<MAX	No Trend	NO	
200	Zinc	<MEAN+2SD,<MAX	>MEAN+2SD, >MAX	No Trend	YES	PROBPLOT: One population. Sediment concentrations indicate overall influence of historical mining wastes and not anthropogenic contamination on the sediments.
201	Zinc	>MEAN+2SD, >MAX	>MEAN+2SD, >MAX	No Trend	YES	PROBPLOT: One population. Sediment concentrations indicate overall influence of historical mining wastes and not anthropogenic contamination on the sediments.
202	Zinc	<MEAN,<MAX	<MEAN+2SD, >MAX	No Trend	YES	PROBPLOT: One population. Sediment concentrations indicate overall influence of historical mining wastes and not anthropogenic contamination on the sediments.

Notes:
IHSS - Individual Hazardous Substance Site.
ND = Not detected.
N/A = Not analyzed in OU 3.
NA = Benchmark data not available.
*Chemical is an essential nutrient.
<MEAN = OU 3 mean value is less than background or benchmark mean value.

>MEAN = OU 3 mean value is greater than background or benchmark mean value.
<MAX = maximum value.
>MAX = OU 3 maximum value is less than background or benchmark maximum value.
>MAX = OU 3 maximum value is greater than background or benchmark maximum value.
MEAN + 2SD = upper-bound background mean (i.e., mean plus two standard deviations).

Column 1: IHSS 200: Great Western Reservoir; IHSS 201: Standley Lake; IHSS 202: Mower Reservoir.
Column 3: Comparison of OU 3 stream to Background Geochemical Characterization Report stream sediments data and Lowry Landfill Background stream sediments data.
Column 4: Comparison of OU 3 reservoir to benchmark literature lake data.
Column 5: No Trend = spatial analysis indicates no contamination from the Site. Spatial distribution is consistent with physical properties associated with natural deposition.
Column 6: Yes = chemical was analyzed using PROBPLOT, No = not analyzed using PROBPLOT.
Column 7: Discussion of weight-of-evidence results.

discussion of the COC selection process can be found in TM 4 (DOE, 1994d). The background/ benchmark comparison for radionuclides is presented below.

Mean and maximum activities for americium-241 in stream sediments for all three IHSSs were below mean (0.070 pCi/g) and maximum (0.82 pCi/g) background stream sediment values. The mean values for americium-241 are 0.017, 0.022, and 0.030 pCi/g for IHSSs 200, 201, and 202, respectively. The maximum activity for americium-241 in creek sediments (0.080 pCi/g) was found in IHSS 201 (Standley Lake) at location SED00992 (see Figure 2-4).

The maximum plutonium-239, -240 activity in OU 3 stream surface sediments (0.55 pCi/g) was measured in Great Western Reservoir at location SED00192 (see Figure 2-3). This value does not exceed the maximum background stream sediment value (2.36 pCi/g). The mean activities for plutonium-239, -240 in stream sediments for all three IHSSs do not exceed the background mean value (0.170 pCi/g). The mean stream sediment values for plutonium-239, -240 are 0.156, 0.082, and 0.091 pCi/g for IHSSs 200, 201, and 202, respectively.

Mean activities for uranium-233, -234 in stream sediments for all three IHSS were below the mean background stream sediment value (1.680 pCi/g). The mean activities are 1.369, 1.452, and 1.288 pCi/g for IHSSs 200, 201, and 202, respectively. The maximum activities for uranium-233, -234 in stream sediments for IHSS 200 (2.66 pCi/g) and IHSS 202 (2.09 pCi/g) were less than the maximum background stream sediment value (4.50 pCi/g). The maximum activity for uranium-233, -234 in stream sediments in IHSS 201 (4.70 pCi/g) slightly exceeded the maximum background stream sediment value. This maximum activity was measured at location SED01592.

Mean activities of uranium-235 in stream sediments in all three IHSSs were less than the upper-bound value (mean plus two standard deviations) for background stream sediments (0.161 pCi/g). The mean activities for uranium-235 were 0.072, 0.078, and 0.085 pCi/g for IHSSs 200, 201, and 202, respectively. The maximum activity for uranium-235 in OU 3 stream sediments (0.20 pCi/g) was measured in Great Western Reservoir at location SED02492 (see Figure 2-3). This value slightly exceeded the maximum background stream sediment value (0.19 pCi/g).

Mean uranium-238 activities in stream sediments for all three IHSSs were less than or equal to the mean background stream sediment value (1.40 pCi/g). The mean activities for uranium-238 were 1.400, 1.339, and 1.205 pCi/g for IHSSs 200, 201, and 202, respectively. Maximum values for uranium-238 in IHSS 200 and IHSS 202 were below the background stream sediment maximum value (3.83 pCi/g). The maximum value for uranium-238 in stream sediments in IHSS 201 (3.90 pCi/g) slightly exceeded the background stream sediment maximum value (3.82 pCi/g); the maximum value for IHSS 201 was measured at location SED01592 (see Figure 2-4).

Data Summary for Reservoir Surface Sediments

Table 4-5 also summarizes the benchmark comparisons for OU 3 reservoir surface sediment samples (nearshore sediment grab samples and reservoir grab samples). The concentrations/activities of radionuclides and other metals detected in the OU 3 reservoir sediments are within background levels with the exception of Great Western Reservoir which has elevated levels of plutonium. Based on the comparison between the OU 3 data and the background and benchmark data, none of the other analytes significantly exceed background levels. All reservoir sediment analytes were evaluated by the COC selection process. The results of this evaluation indicated that there were no COCs requiring further evaluation for the human health risk assessment in the reservoir sediments of OU 3 with the exception of plutonium-239, -240 in Great Western Reservoir. This is the only COC identified for further evaluation. A detailed discussion of the COC selection process can be found in TM 4 (DOE, 1994d). Volatile organic compound analysis of the Mower Reservoir sediments detected low concentration levels. These analytes were not retained as COCs and are discussed in the following subsections along with the radionuclides.

Radionuclides - Benchmark reservoir data were only available for uranium. Therefore, OU 3 reservoir sediment data were also compared to background stream sediment data. Based on a comparison of OU 3 data to background stream reservoir sediment data in the Background Geochemical Characterization Report (DOE, 1993a) and to benchmark data, activities of radionuclides in OU 3 reservoir sediments were within background levels for all three IHSSs (Table 4-5). The one exception is plutonium-239, -240 which was elevated above background levels in Great Western Reservoir.

Benchmark reservoir data were not available for americium-241. The OU 3 mean values for americium-241 were 0.043, 0.017, and 0.049 pCi/g for IHSSs 200, 201, and 202, respectively. The maximum activity for americium-241 in reservoir sediments (0.21 pCi/g) was found in Great Western Reservoir at location SED13492. These values were below the background stream sediment mean (0.070 pCi/g) and maximum (0.82 pCi/g) values.

The maximum plutonium-239, -240 activity in OU 3 reservoir sediments (3.30 pCi/g) was measured in Great Western Reservoir (IHSS 200) at location GWR-EG48. This value exceeded the background value of 0.130 pCi/g. The mean activities for plutonium-239, -240 for reservoir sediments were 0.267, 0.033, and 0.291 pCi/g for IHSSs 200, 201, and 202, respectively. The mean values for IHSSs 200 and 202 exceeded the stream background sediment mean (0.170 pCi/g) value and the benchmark reservoir mean (0.13 pCi/g).

The maximum uranium-233, -234 activity in OU 3 reservoir sediments (5.40 pCi/g) was measured in Great Western Reservoir at location SED06692. This value was below the mean benchmark value of 11.4 pCi/g. The mean activities for uranium-233, -234 for reservoir sediments were 1.345, 1.238, and 1.407 pCi/g for IHSSs 200, 201, and 202, respectively. Mean activities for uranium-233, -234 in reservoir sediments for all three IHSSs were below the mean background stream sediment value (1.680 pCi/g).

The maximum uranium-235 activity in OU 3 reservoir sediments (0.56 pCi/g) was measured in Great Western Reservoir at location SED06692. This value was below the mean benchmark value of 11.4 pCi/g for reservoir sediments. The mean activities for uranium-235 for reservoir sediments were 0.071, 0.045, and 0.064 for IHSSs 200, 201, and 202, respectively. Mean activities for uranium-235 in reservoir sediments for all three IHSSs were less than the upper-bound value (mean plus two standard deviations) for background stream sediments (0.161 pCi/g) and less than the maximum background stream sediment value (0.19 pCi/g).

The maximum uranium-238 activity in OU 3 sediments (4.40 pCi/g) was measured in Great Western Reservoir at location SED06692. This value was below the mean benchmark value of 11.4 pCi/g for reservoir sediments. The mean activities for uranium-238 for reservoir sediments were 1.339, 1.223, and 1.502 for IHSSs 200, 201, and 202, respectively. The mean activities for IHSS 200 and 201 were below the mean background stream sediment value (1.40 pCi/g), while the mean activity for IHSS 202 was above the mean background value. Maximum values for IHSSs 201 and 202 were below the background stream sediment value (3.82 pCi/g).

The maximum concentrations of the uranium isotopes occurred at the same sampling location in Great Western Reservoir, SED06692 (see Figure 2-3).

Volatile Organic Compounds—Volatile organic compounds were analyzed for in Mower Reservoir (IHSS 202) sediment samples only. These data were reviewed in the CDPHE Conservative Screen Letter Report (DOE, 1994e) to determine if any VOCs should be retained as PCOCs.

Six VOCs were detected in sediment samples from IHSS 202 (Mower Reservoir): 2-butanone, acetone, methylene chloride, total xylenes, toluene, and trichlorotrifluoroethane. No other organic compounds were detected in sediment samples. The detected organic compounds were not retained as PCOCS for the CDPHE Conservative Screen for the reasons given below.

- 2-Butanone - Three of 12 samples were detects; all 3 detects were J-qualified, indicating that reported concentration is estimated (i.e., reported concentration is less than the contract-required instrument detection limit, but greater than the instrument detection limit). The laboratory contaminant 2-butanone is common (EPA, 1988); therefore, low levels detected in samples may be due to contamination at the laboratory. The maximum detected concentration was 14.0 mg/kg.

- Acetone - Six of 15 samples were detects; 5 of the 6 detects were J-qualified; 2 of the 6 detects were B-qualified, indicating blank contamination problems. Acetone is a common laboratory contaminant (EPA, 1988). The maximum detected concentration was 47.0 mg/kg.

- Methylene chloride - Three of 14 samples were detects; all detects were J-qualified. Methylene chloride is a common laboratory contaminant (EPA, 1988). The maximum detected concentration was 5.0 mg/kg.

- Total xylenes - One of 10 samples was a detect; the detect value was J-qualified. The maximum detected concentration was is 2.0 mg/kg.

- Toluene - Three of 11 samples were detects; 2 of 3 detects were J-qualified. Toluene is a common laboratory contaminant (EPA, 1988). The maximum detected concentration was 16.0 mg/kg.

- Trichlorotrifluoroethane - Only one sample was analyzed for trichlorotrifluoroethane; the detected value was 50.0 mg/kg and was J- and B-qualified.

These six organic compounds detected in Mower Reservoir were not retained as PCOCs based on detection frequency, laboratory qualification (e.g., J qualification), low concentration levels, and the presence of some compounds in the corresponding blank samples (e.g., B-qualifier indicates "detects," which likely represent contamination or laboratory artifacts). (Note: Laboratory blank data were not available to compare concentrations of organic compounds in the OU 3 samples to concentrations in the laboratory blanks.) This conclusion is supported by the Phase I Health Studies, which did not identify 2-butanone, acetone, total xylenes, toluene, or trichlorotrifluoroethane as materials of concern (CDPHE, 1992).

4.5.2 Subsurface Sediment Data Summary

A total of 155 subsurface sediment samples (excluding QC samples) were collected from 20 sample locations during the OU 3 RFI/RI field investigation. The RFI/RI subsurface sediment data consisted of 5 core samples collected from IHSS 200, 5 core samples collected from IHSS 201, and 3 core samples collected from IHSS 202. The samples were analyzed for radionuclides and metals. Subsurface core samples were only collected in reservoir areas.

Table 4-6 summarizes the background and benchmark comparisons for all analytes in subsurface sediments.

Radionuclides

OU 3 subsurface sediment activities for radionuclides were compared to benchmark surface and subsurface sediment activities. In general, activities of radionuclides were below benchmark values. The exception was plutonium-239, -240; activities of plutonium-239, -240 in all three reservoirs exceeded benchmark subsurface sediment values.

Benchmark sediment data were not available for americium-241, so the OU 3 subsurface data were compared to the background stream sediment data from the Background Geochemical Characterization Report (DOE, 1993a). The mean activity for americium-241 in Great Western Reservoir (0.24 pCi/g) was less than the background stream sediment upper-bound value (mean plus two standard deviations, 0.45 pCi/g). Mean activities for americium-241 in Standley Lake (0.02 pCi/g) and Mower Reservoir (0.04 pCi/g) were less than the background stream sediment mean (0.07 pCi/g). Maximum activities for americium-241 in Standley Lake (0.18 pCi/g) and Mower Reservoir (0.17 pCi/g) were less than the background stream sediment maximum (0.82 pCi/g). The maximum value for americium-241 in subsurface sediments (1.02 pCi/g) was measured at location SED08692 in Great Western Reservoir at a depth of 26 to 28 inches (see Figure 2-3).

The maximum activities for plutonium-239, -240 in Great Western Reservoir (4.03 pCi/g), Standley Lake (0.38 pCi/g), and Mower Reservoir (1.11 pCi/g) exceeded the maximum subsurface sediment benchmark activity (0.19 pCi/g). The maximum plutonium-239, -240 activity in OU 3 subsurface sediments (4.03 pCi/g) was measured at location SED09192 in Great Western Reservoir at a depth of 18 to 20 inches.

Through the COC evaluation process, plutonium-239, -240 was only retained as a COC for Great Western Reservoir in the subsurface sediments. As part of the process, plutonium levels are compared with the PRGs. The only plausible PRG for subsurface sediments reflects exposure for a construction worker. This PRG (2851 pCi g) is well above the maximum values detected in any of the reservoir sediments (4.03 pCI/g, Great Western Reservoir). Plutonium was retained as a COC in Great Western Reservoir to evaluate the maximum exposure risk, and because there is some uncertainty regarding the future use of this reservoir. Details of the COC selection process for subsurface reservoir sediments can be found in TM 4 (DOE, 1994d).

For the uranium isotopes, maximum values for all isotopes in the three reservoirs were below benchmark values. Maximum values for uranium-233, -234 for Great Western Reservoir (3.90 pCi/g), Standley Lake (3.15 pCi/g), and Mower Reservoir (1.73 pCi/g) were below the maximum benchmark value of 11.4 pCi/g for uranium in surface sediments. Maximum values for uranium-235 for Great Western Reservoir (0.21 pCi/g), Standley Lake (0.20 pCi/g), and Mower Reservoir (0.13 pCi/g) were also below the maximum benchmark value of 11.4 pCi/g for uranium in surface sediments. Finally, maximum

Table 4-6

Background/Benchmark Comparison Results Subsurface Sediment Cores
Rocky Flats Environmental Technology Site

1 IHSS	2 Chemical	3 Background-Creek and Lake Surface Sediments	4 Benchmark Lake Subsurface Sediments Evaluation
200	^{241}Am	<MEAN+2SD,>MAX	NA
201	^{241}Am	<MEAN, <MAX	N/A
202	^{241}Am	<MEAN, <MAX	N/A
200	Aluminum	<MEAN, <MAX	NA
201	Aluminum	<MEAN+2SD,<MAX	N/A
202	Aluminum	<MEAN+2SD,<MAX	N/A
201	Antimony	<MEAN+2SD,>MAX	N/A
202	Antimony	ND	ND
200	Arsenic	<MEAN, <MAX	>MEAN
201	Arsenic	>MEAN+2SD,>MAX	>MEAN
202	Arsenic	<MEAN+2SD,<MAX	>MEAN
200	Barium	<MEAN, <MAX	NA
201	Barium	<MEAN+2SD,>MAX	N/A
202	Barium	<MEAN+2SD,>MAX	N/A
200	Beryllium	<MEAN+2SD,<MAX	<MEAN
201	Beryllium	<MEAN+2SD,>MAX	<MEAN
202	Beryllium	<MEAN+2SD,>MAX	<MEAN
200	Cadmium	<MEAN, <MAX	>MEAN
201	Cadmium	>MEAN+2SD,>MAX	>MEAN
202	Cadmium	ND	ND
200	Calcium	<MEAN+2SD,<MAX	>MEAN
201	Calcium	<MEAN+2SD,<MAX	>MEAN
202	Calcium	<MEAN+2SD,>MAX	>MEAN
200	Cesium	<MEAN, <MAX	NA
201	Cesium	<MEAN, <MAX	N/A
202	Cesium	ND	ND
200	Chromium	<MEAN+2SD,>MAX	NA
201	Chromium	<MEAN+2SD,>MAX	N/A
202	Chromium	<MEAN+2SD,>MAX	N/A
200	Cobalt	<MEAN+2SD,>MAX	NA
201	Cobalt	<MEAN+2SD,>MAX	N/A
202	Cobalt	<MEAN+2SD,>MAX	N/A
200	Copper	>MEAN+2SD,>MAX	NA
201	Copper	>MEAN+2SD,>MAX	N/A
202	Copper	<MEAN+2SD,>MAX	N/A
200	Cyanide	ND	ND
200	Iron	<MEAN+2SD,<MAX	>MEAN
201	Iron	>MEAN+2SD,>MAX	>MEAN
202	Iron	<MEAN+2SD,>MAX	>MEAN
200	Lead	<MEAN+2SD,>MAX	>MEAN
201	Lead	>MEAN+2SD,>MAX	>MEAN
202	Lead	<MEAN+2SD,>MAX	>MEAN

Table 4-6 (continued)

1 IHSS	2 Chemical	3 Background-Creek and Lake Surface Sediments	4 Benchmark Lake Subsurface Sediments Evaluation
200	Lithium	<MEAN+2SD,<MAX	NA
201	Lithium	<MEAN+2SD,<MAX	N/A
202	Lithium	<MEAN+2SD,<MAX	N/A
200	Magnesium	<MEAN+2SD,<MAX	NA
201	Magnesium	<MEAN+2SD,<MAX	N/A
202	Magnesium	<MEAN+2SD,<MAX	N/A
200	Manganese	<MEAN+2SD,<MAX	NA
201	Manganese	>MEAN+2SD,<MAX	N/A
202	Manganese	<MEAN+2SD,>MAX	N/A
200	Mercury	<MEAN+2SD,>MAX	>MEAN
201	Mercury	>MEAN+2SD,>MAX	>MEAN
202	Mercury	<MEAN, >MAX	<MEAN
200	Molybdenum	<MEAN, <MAX	NA
201	Molybdenum	<MEAN+2SD,>MAX	N/A
202	Molybdenum	ND	ND
200	Nickel	<MEAN+2SD,<MAX	>MEAN
201	Nickel	>MEAN+2SD,>MAX	>MEAN
202	Nickel	<MEAN+2SD,<MAX	>MEAN
200	Potassium	<MEAN+2SD,<MAX	NA
201	Potassium*	>MEAN+2SD,>MAX	N/A
202	Potassium*	>MEAN+2SD,>MAX	N/A
200	$^{239/240}Pu$	<MEAN+2SD,>MAX	>MAX
201	$^{239/240}Pu$	<MEAN, <MAX	N/A
202	$^{239/240}Pu$	<MEAN+2SD,<MAX	N/A
200	Selenium	<MEAN+2SD,<MAX	<MEAN
201	Selenium	<MEAN+2SD,>MAX	<MEAN
202	Selenium	<MEAN+2SD,>MAX	>MEAN
200	Silver	<MEAN+2SD,>MAX	NA
201	Silver	>MEAN+2SD,>MAX	N/A
202	Silver	<MEAN+2SD,<MAX	N/A
200	Sodium	<MEAN, <MAX	NA
201	Sodium	<MEAN+2SD,<MAX	N/A
202	Sodium	<MEAN+2SD,<MAX	N/A
200	Strontium	<MEAN+2SD,<MAX	NA
201	Strontium	<MEAN+2SD,<MAX	N/A
202	Strontium	<MEAN+2SD,<MAX	N/A
200	Thallium	ND	ND
201	Thallium	ND	N/A
202	Thallium	ND	ND
200	Tin	<MEAN, <MAX	NA
201	Tin	<MEAN, <MAX	N/A
202	Tin	<MEAN+2SD,>MAX	N/A

Table 4-6 (continued)

1 IHSS	2 Chemical	3 Background-Creek and Lake Surface Sediments	4 Benchmark Lake Subsurface Sediments Evaluation
200	$^{233/234}U$	<MEAN, <MAX	<MAX
201	$^{233/234}U$	<MEAN+2SD,<MAX	N/A
202	$^{233/234}U$	<MEAN, <MAX	N/A
200	^{235}U	<MEAN, >MAX	<MAX
201	^{235}U	<MEAN+2SD,>MAX	N/A
202	^{235}U	<MEAN, <MAX	N/A
200	^{238}U	<MEAN, <MAX	>MAX
201	^{238}U	<MEAN+2SD,<MAX	N/A
202	^{238}U	<MEAN, <MAX	N/A
200	Vanadium	<MEAN+2SD,<MAX	>MEAN
201	Vanadium	<MEAN+2SD,<MAX	>MEAN
202	Vanadium	<MEAN+2SD,<MAX	>MEAN
200	Zinc	<MEAN+2SD,<MAX	>MEAN
201	Zinc	>MEAN+2SD,>MAX	>MEAN
202	Zinc	<MEAN+2SD,<MAX	<MEAN

Notes:
IHSS - Individual Hazardous Substance Site.
ND = Not detected.
N/A = Not analyzed in OU 3.
NA = Benchmark data not available.
*Chemical is an essential nutrient.
<Mean = OU 3 mean value is less than background or benchmark mean value.
>Mean = OU 3 mean value is greater than background or benchmark mean value.
<Max = OU 3 maximum value is less than background or benchmark maximum value.
>Max = OU 3 maximum value is greater than background or benchmark maximum value.
MAX = maximum value.
MEAN+2SD = upper bound background mean (i.e., mean plus two standard deviations).

Column 1: IHSS 200: Great Western Reservoir; IHSS 201: Standley Lake; IHSS 202: Mower Reservoir.
Column 3: Comparison of OU 3 reservoir to Background Geochemical Characterization Report stream sediments data (DOE, 1993a), Lowry Landfill Background Stream Sediment data (EPA, 1992a), benchmark lake surface sediment data (CCBA, 1994).
Column 4: Comparison of OU 3 reservoir to benchmark lake subsurface sediment data (Heit, 1984; Cohen et al., 1990)

values for uranium-238 for Great Western Reservoir (3.30 pCi/g), Standley Lake (2.86 pCi/g), and Mower Reservoir (1.80 pCi/g) were below the maximum benchmark value of 11.4 pCi/g for uranium in surface sediments.

Subsurface sediment data was also collected by the City of Broomfield during the spring of 1991. Subsurface core samples were collected to evaluate the plutonium-239, -240 levels in the near shore sediments. Samples were taken around the reservoir in a zone between the normal high water mark, and 15 feet below the high water mark. The results of this study differ from the results of the OU 3 RI sampling effort. The Broomfield data exhibited elevated levels of plutonium in the Walnut Creek inlet area. The maximum value observed was 16.00 pCi/g plutonium-239, -240 at a depth of 12 inches beneath the sediment surface. The OU 3 RI sampling effort was not able to reproduce this result. The maximum value observed in the OU 3 data is 4.03 pCi/g plutonium. This value was found in the deepest portion of the reservoir at a depth of 18 inches beneath the sediment surface. The Broomfield data are not used in this report because the quality assurance criteria cannot be verified. Qualitative comparisons suggest that the two data sets are comparable and consistent with one another, and that the OU 3 data set is representative of the subsurface sediments of the reservoir.

Metals

Concentrations of metals in OU 3 subsurface sediments were compared to stream sediment background values and surface and subsurface benchmark values. As shown in Table 4-6, Great Western Reservoir mean concentrations of all metals except copper were less than the upper-bound background stream sediment values (mean plus two standard deviations). For Standley Lake, mean concentrations of arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, potassium, silver, and zinc exceeded upper-bound background stream sediment values. For Mower Reservoir, mean concentrations of all metals except potassium were less than the upper-bound background stream sediment values. The COC selection process eliminated all metals as COC in the subsurface sediments. Details of this process can be found in TM 4 (DOE, 1994d).

4.5.3 Spatial Analysis

For purposes of spatial analysis, both surface and subsurface sediment data are combined in the following discussions. Figures I-1 through I-6 in Appendix I are maps showing the activities of radionuclides and concentrations of selected metals at each OU 3 sampling location for sediments. Figures I-7 through I-9 show sitewide concentrations of selected metals.

Sediment Behavior

Available data show that concentrations of radionuclides and metals were highest in the middle of the three water bodies, with randomly distributed values along the shoreline (Figures I-1 through I-6). There is no definitive spatial trend in surface sediments; suggesting a natural, randomly distributed population. The slightly elevated contaminant levels in the middle of the three water bodies can be explained by natural limnological phenomena. The shoreline sediments are exposed the majority of the year, and wind and water erosion preferentially remove the finer-grained particles. The finer sediment particles tend to have the highest organic matter concentrations and thus higher contaminant concentrations (Davis and Kent, 1990). These finer particles in the water column tend to deposit in the center of the lake where flow velocities can no longer support particle suspension.

The slightly higher concentrations in the middle of the reservoirs are seen in all three IHSSs. However, these higher concentrations are not indicative of contamination, rather, they may be explained by natural processes.

Sitewide Concentrations of Metals

Figures I-7 through I-12 are maps that show sitewide concentrations of selected metals (arsenic, cadmium, copper, lead, nickel, and zinc) in sediments. For core samples in the reservoirs, the maximum value at each location is shown on the maps.

As shown in Figures I-7 through I-12, the majority of the sediment samples collected within Rocky Flats boundaries and from OU 3 have metals concentrations below stream sediment UTLs reported in the Background Geotechnical Characterization Report (DOE, 1993c). These data show that the highest concentrations for these metals tend to be in the deeper areas of Standley Lake. As discussed in the previous subsection, natural limnological phenomena explain the slightly elevated concentrations of metals in the center of the reservoir. It is also important to note Standley Lake receives approximately 90 percent of its water from Clear Creek and the Clear Creek drainage area, which includes the Central City/Clear Creek mining district. Conversely, Mower Reservoir receives approximately 100 percent of its water from the Rocky Flats drainage area (ASI, 1990). These figures indicate that patterns of metals concentrations sitewide are representative of natural conditions and do not represent Rocky Flats-related contamination.

Sediment Core Profiles

Figures J-1 through J-20 in Appendix J are activity/concentration-depth profiles for radionuclides and selected metals in sediment cores collected from the three reservoirs. In general, patterns of activities for the uranium isotopes and concentrations of metals in the core profiles do not show any consistent peaks or patterns that indicate deposition of contamination from Rocky Flats. The core profiles instead exhibit patterns of natural variability associated with background conditions of metals. Variations in concentrations of metals probably correspond to changes in oxidizing-reducing conditions and consequently, with depth in the sediments.

Plutonium migration is not expected through the sediment column, so peaks in plutonium-239, -240 activity can be used as stratigraphic markers for radionuclide releases (e.g., fallout from weapons testing). The core profiles for plutonium-239, -240 in Great Western Reservoir (IHSS 200) show maximum activities in the deeper areas of the reservoir at depths of approximately 18 to 20 inches. The maximum activity of plutonium-239, -240 in subsurface sediments of Great Western Reservoir (4.03 pCi/g) was measured at location SED09192 at a depth of approximately 18 inches. Data show that the patterns of americium-241 in the sediment profiles are similar to the patterns of plutonium-239, -240 in Great Western Reservoir. The depth range of 18 to 20 inches corresponds to approximately 1969.

Figure 4-9 shows depth profiles for activities of plutonium-239, -240 in core samples from Great Western Reservoir in relation to water depth. As indicated on this figure, the highest levels of plutonium were found in the deeper areas of the reservoir (water depth at SED09192 is approximately 40 feet). This figure also illustrates that the highest activities are buried beneath the sediment surface; thus limiting potential exposure.

The core profiles for plutonium-239, -240 in Standley Lake (IHSS 201) show maximum activities in the deeper areas of the reservoir (at the sediment depth interval of approximately 18 to 32 inches). The maximum activity of plutonium-239, -240 in subsurface sediments of Standley Lake (0.38 pCi/g) was measured at location SED08392 at a depth of approximately 18 inches.

The core profiles for Mower Reservoir (IHSS 202) show maximum activities in sediments at depths of approximately 4 to 8 inches. The maximum activity of plutonium-239, -240 in subsurface sediments of Mower Reservoir (1.11 pCi/g) was measured at location SED08992 at a depth of approximately 6 inches. Field conditions resulted in poor recoveries for core materials in Mower Reservoir and consequently, overall core depths for this reservoir are less than for IHSSs 200 or 201.

Age Dating of Sediment Cores

The DOE (1994c) investigated the sediment history of IHSSs 200, 201, and 202. Radionuclide fallout from peak weapons testing during 1963 and the 1969 903 Pad area clean-up activities, as well as a potential air-borne release of plutonium from a 1969 Rocky Flats building fire, provided sediment markers within cores extracted from the three reservoirs. Appendix K contains the sediment dating report. Peak activities of cesium-137 and plutonium-239, -240 provided a means to date horizons. Radioisotope sediment dating for Great Western Reservoir, Standley Lake, and Mower Reservoir indicated sedimentation rates of 0.9 (inches per year,) 0.75 in/yr, and 0.3 in/yr, respectively. Using these sedimentation rates, radionuclide contamination in the sediment could be traced back to the corresponding years of release. Because sediment dating between core pairs was statistically identical, sampling process and migration minimally affected the distribution of cesium-137 and plutonium-239,-240. Aerial fallout from peak weapons testing during 1963 and the releases in 1969 provided sediment markers within cores extracted from IHSSs 200, 201, and 202. Both Krey and Hardy (1970) and the CDPHE (1992) concluded that historic releases from the 903 Pad were responsible for most of the airborne contamination to the offsite areas. These studies also conclude that the contribution from other sources such as the 1969 and 1957 fires, and chronic stack emissions were minimal. Figure 4-7 (DOE,1994c) illustrates cesium-137 and plutonium-239, -240 activities with depth and corresponding years for SED09192, the core location exhibiting the maximum plutonium-239, -240 activity in Great Western Reservoir.

Sources of Water

Standley Lake receives approximately 90 percent of its water from Clear Creek and the Clear Creek drainage area that includes the Central City/Clear Creek mining district. Conversely, Mower Reservoir receives approximately 100 percent of its water from the Rocky Flats drainage area (ASI, 1990). Based on these water sources and sediment sources, it is expected that higher concentrations of Rocky Flats-related metals would be found in Mower Reservoir than in Standley Lake. Tables 4-6 and 4-7 indicate that all metals except calcium in surface sediments and potassium in subsurface sediments were found at background levels in Mower Reservoir, the water body that receives essentially all of its water from Rocky Flats-related drainages. Although some metals have concentrations elevated above background and benchmark levels in Standley Lake (i.e., arsenic, cadmium, copper, iron, manganese, mercury, nickel, silver, and zinc), it appears that these metals are not associated with releases from Rocky Flats because the same metals are not elevated above background levels in Mower Reservoir.

4.5.4 Probability Plot Analysis

A probability plot analysis was performed on selected chemicals in surface sediments to assess whether a chemical concentration/activity data set (i.e., population) represents either a background (natural or anthropogenic in the case of global fallout of radionuclides) or contaminated population. This analysis was performed using a statistical software program called PROBPLOT, which defines the number of populations present and the concentration/activity range for each population.

The analysis indicated the presence of one statistically-normal population for each of the metals and radionuclides in each of the IHSSs with the exception of aluminum, chromium, manganese, and plutonium-239, -240 in Mower Reservoir, and chromium in Great Western Reservoir (IHSS 200). In these cases where two populations were identified, the concentration/activity variations represent subpopulations within the population that are attributed to geochemical (complexation, adsorption, dissolution, precipitation), organic (aquatic organisms, plants, and detritus), and physical processes (transport and deposition) that collectively cause natural variability. These results support the background/benchmark comparison and spatial analysis conclusions that levels of radionuclides, apart from plutonium-239, -240 in Great Western Reservoir, and metals in sediments, are representative of background conditions and are not a result of contamination from Rocky Flats.

4.5.5 Sediment Summary

IHSS 200

Based on the background and benchmark comparisons, all radionuclides except plutonium-239, -240 were found at background levels in sediments in Great Western Reservoir. Americium levels were also found to be within background levels. Plutonium was found to be elevated in the subsurface sediments relative to background but was eliminated as a COC in the selection process. In addition, metals were found to be present in surface sediments within naturally occurring background levels, except copper, which was elevated above background levels in subsurface sediments. The COC selection process identified plutonium-239, -240 as the one COC for sediments in Great Western Reservoir. Copper was eliminated in the COC selection process based on the Concentration-Toxicity screen.

IHSS 201

In general, activities of radionuclides in Standley Lake sediments were found at background levels with the exception of plutonium in subsurface sediments. Concentrations of some metals in subsurface sediments (i.e., arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, potassium, silver, and zinc) exceeded the stream sediment background levels. However, spatial analysis and information about sources of water feeding Standley Lake indicate that these metals are not associated with releases from Rocky Flats. Based on the spatial analysis, these analytes were eliminated as PCOCs in the CDPHE COC selection process. The COC selection process also eliminated plutonium in the subsurface sediments as a COC. No analytes were identified as COCs for sediments in Standley Lake.

IHSS 202

All radionuclides and metals were found at background levels in Mower Reservoir except calcium in surface sediments and plutonium and potassium in subsurface sediments. No analytes were identified as COCs for sediments in Mower Reservoir. Calcium and Potassium were eliminated as COCs because they are essential human nutrients, plutonium was eliminated because it falls below the PRG.

4.6 GROUNDWATER EVALUATIONS

As described in the OU 3 RFI/RI Work Plan, the purpose of the groundwater sampling was to characterize hydrogeology downgradient from the reservoirs and to assess media interactions between the reservoirs and the groundwater. The data evaluations performed include water typing, summary statistics, and a qualitative comparison to background.

4.6.1 Data Summary

Two groundwater monitoring wells were installed during the OU 3 field investigation; one downstream of Great Western Reservoir (IHSS 200, Well 49192) and one downstream of Standley Lake (IHSS 201, Well 49292). The wells were installed to evaluate the potential interaction between the reservoirs and groundwater. In addition, groundwater samples were collected to obtain OU 3-specific hydrogeologic data. The groundwater results indicate analytes are not elevated above background levels. As discussed previously, most analytes do not have concentrations elevated over background levels in surface water and/or sediments. Therefore, contamination does not appear to be migrating from surface water or sediments to groundwater.

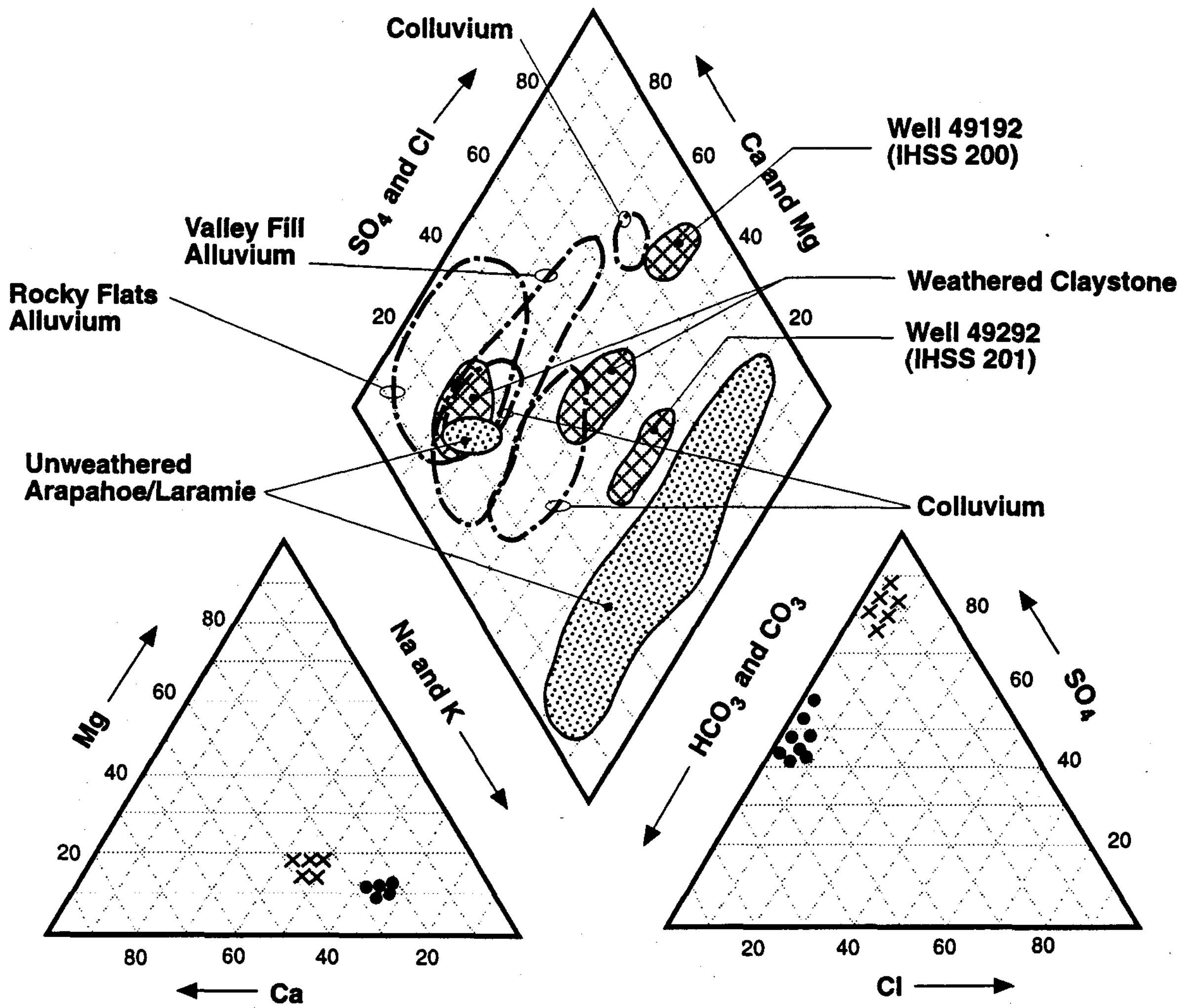
Groundwater samples collected from the wells were analyzed for both dissolved and total metals, dissolved and total uranium-233, -234, uranium-235, total plutonium-239, -240, total americium-241, and water-quality parameters. Each well was sampled eight times during 1993 (in January, April, May, June, July, August, and September). Dissolved analysis are defined as constituents that pass through a 0.45-micron membrane filter. Total analysis are unfiltered samples that may contain suspended particulates of clay-sized particles from sediment or the surrounding geologic materials. From a groundwater flow and transport perspective, the dissolved analysis are generally more useful.

A summary of the OU 3 groundwater analytical results for each well is presented in Appendix C. The summary statistics (number of detects, number of samples, frequency of detection, minimum nondetect, maximum nondetect, minimum detect, maximum detect, arithmetic mean, geometric mean, standard deviation, normal 95 percent UCL, and lognormal upper 95 percent confidence limit) are summarized by well location in Appendix C. In addition, background data for groundwater are included in Appendix C.

To evaluate whether OU 3 groundwater data exceed background data, the OU 3 data were compared to the groundwater data sets presented in the Background Geochemical Characterization Report (DOE, 1993c). The background groundwater monitoring wells were selected to be representative of the UHSU (Rocky Flats alluvium, colluvium, valley fill alluvium, weathered claystone); and the LHSU (the unweathered Arapahoe and Laramie formation bedrock).

A Piper diagram showing major ion chemistry for the OU 3 groundwater wells and background UHSU and LHSU is presented in Figure 4-10. The concentrations of the major anions (as meq/L [milliequivalents per liter]) are given as percentages of the total milliequivalents per liter. The groundwater collected from Well 49192 (IHSS 200) is sodium-sulfate enriched, whereas the groundwater from Well 49292 (IHSS 201) is sodium-enriched with no dominant anion. As illustrated in Figure 4-10, the wells screened in the UHSU have a variable composition. Groundwater in the LHSU generally exhibits a sodium-sulfate to sodium-bicarbonate chemistry. For background comparison purposes, data from well 49192 (IHSS 200) were compared to concentrations in the UHSU, whereas data from Well 49292 (IHSS 201) was compared to the LHSU because of the similarity in their water chemistry.

A number of reasons exist for spatial changes and differences in groundwater chemistry. Some changes may be due to the natural evolution of groundwater chemistry along a flow path, such as an increase in total dissolved solids (TDS) content in the downgradient direction. Other changes in water chemistry may be the result of ion-exchange processes, oxidation/reduction reactions, or mineral precipitation/ dissolution processes. However, the similarity of the water typing for the OU 3 wells compared to the



Alluvial, Colluvium
Weathered Claystone
} Upper Hydrostratigraphic Unit (UHSU)

Unweathered Sandstone } Lower Hydrostratigraphic Unit (LHSU)

Well 49192 Cations and Anions

Well 49292 Cations and Anions

Figure 4-10
Piper Diagram Showing Major Ion Chemistry For OU 3 Wells and Background Geochemical Groundwater Wells

background data groupings provides a suitable data set for determining if OU 3 data are consistently above background, in conjunction with the temporal, analytical uncertainty, and geochemical evaluations.

Data from Well 49192 contain one anomaly that may have influenced analytical results. Three of the eight sample rounds had elevated amounts of total suspended solids (TSS). On January 29, 1993, April 29, 1993, and November 18, 1993, TSS were 840, 1300, and 948 mg/l, respectively. On the five other sample dates, the TSS were all less than 160 mg/l. The elevated amount of TSS, in conjunction with elevated total aluminum and total iron (over one order of magnitude greater than the other five sampling rounds), indicate that the sampling technique on those days may be suspect. The correlation coefficients between TSS and aluminum and TSS and iron are 0.99 and 0.96, respectively. A high correlation coefficient (0.8 to 1.0) indicates that the metals are more likely contained in the suspended sediments rather than in solution. The elevated TSS and subsequent elevated metals from this well may be due to sampling technique. When the sampling bailer was lowered in the well, the bailer may have hit the bottom of the well and dislodged sediments into the water column.

TSS in Well 49292 ranged from 6 to 9 mg/l during the eight sample rounds, indicating no high concentrations of suspended materials are present in the groundwater and that good sampling techniques were used during well sampling.

4.6.2 Background Comparison

Table 4-7 summarizes the background and benchmark comparisons for OU 3 groundwater data. In general, all analytes were found at naturally-occurring background levels in OU 3 groundwater. In addition, all analytes were evaluated in the COC selection process, and all analytes were eliminated as COCs in groundwater. The following subsections present details for analytes detected at levels above background and benchmark values.

Radionuclides

Mean activities for all radionuclides in both wells were less than the upper-bound background mean values. In addition, maximum values for radionuclides in the OU 3 wells were less than background maximum values except for uranium-235 and uranium-238 in Well 49292. The maximum activity for uranium-235 in Well 49292 was 0.083 pCi/l and the maximum background activity was 0.04 pCi/l. The maximum activity for uranium-238 in Well 49292 was 0.91 pCi/l and the maximum background activity was 0.53 pCi/l.

Metals

Based on the background and benchmark comparisons, concentrations of metals in OU 3 groundwater were within naturally-occurring levels. The two exceptions were potassium and strontium in Well 49192. The maximum concentration of potassium in Well 49192 was 14,800 µg/l; the maximum background concentration for potassium was 8,370 µg/l; and the maximum benchmark value for potassium was 10,000 µg/l. The maximum concentration of strontium in Well 49192 was 5,590 µg/l; the maximum background concentration for strontium was 1,770 µg/l; and the maximum benchmark value for strontium was 4,000 µg/l.

Table 4-7
Background/Benchmark Comparison Results for OU 3 Groundwater

1 IHSS	2 Chemical	3 Background Geo. Char. (49192/Upper, 49292/Lower)	4 Benchmark Evaluation
200	ALUMINUM	<MEAN + 2SD,>MAX	>MAX
201	ALUMINUM	<MEAN,MAX	<MAX
200	AMERICIUM -241	<MEAN,MAX	NA
201	AMERICIUM -241	<MEAN,MAX	NA
200	ANTIMONY	<MEAN,MAX	NA
201	ANTIMONY	ND	ND
200	ARSENIC	<MEAN + 2SD,>MAX	<MAX
201	ARSENIC	<MEAN,MAX	<MAX
200	BARIUM	<MEAN,MAX	<MAX
201	BARIUM	<MEAN,MAX	<MAX
200	BERYLLIUM	<MEAN,MAX	<MAX
201	BERYLLIUM	ND	ND
200	CADMIUM	<MEAN + 2SD,<MAX	>MAX
201	CADMIUM	ND	ND
200	CALCIUM	>MEAN + 2SD,MAX	<MAX
201	CALCIUM	>MEAN + 2SD,MAX	<MAX
200	CESIUM	<MEAN,MAX	
201	CESIUM	ND	
200	CHROMIUM	<MEAN + 2SD,<MAX	>MAX
201	CHROMIUM	<MEAN,MAX	<MAX
200	COBALT	<MEAN,MAX	>MAX
201	COBALT	ND	ND
200	COPPER	<MEAN + 2SD,<MAX	>MAX
201	COPPER	<MEAN,MAX	<MAX
200	IRON	<MEAN + 2SD,MAX	>MAX
201	IRON	<MEAN,MAX	<MAX
200	LEAD	<MEAN + 2SD,<MAX	>MAX
201	LEAD	<MEAN,MAX	<MAX
200	LITHIUM	>MEAN + 2SD,MAX	<MAX
201	LITHIUM	<MEAN + 2SD,MAX	<MAX
200	MAGNESIUM	>MEAN + 2SD,MAX	<MAX
201	MAGNESIUM	>MEAN + 2SD,MAX	<MAX
200	MANGANESE	>MEAN + 2SD,MAX	<MAX
201	MANGANESE	<MEAN,MAX	<MAX
200	MERCURY	ND	ND
201	MERCURY	ND	ND
200	MOLYBDENUM	ND	ND
201	MOLYBDENUM	<MEAN,MAX	<MAX
200	NICKEL	<MEAN + 2SD,MAX	<MAX
201	NICKEL	ND	ND
200	PLUTONIUM -239/240	<MEAN + 2SD,MAX	NA
201	PLUTONIUM -239/240	<MEAN + 2SD,MAX	NA
200	POTASSIUM	>MEAN + 2SD,>MAX	>MAX
201	POTASSIUM	<MEAN + 2SD,MAX	<MAX
200	SELENIUM	<MEAN,MAX	<MAX
201	SELENIUM	ND	ND
200	SILICON	<MEAN + 2SD,>MAX	<MAX
201	SILICON	<MEAN,MAX	<MAX
200	SILVER	ND	ND
201	SILVER	ND	ND

Table 4-7 (continued)

1 IHSS	2 Chemical	3 Background Geo. Char. (49192/Upper, 49292/Lower)	4 Benchmark Evaluation
200	SODIUM	>MEAN + 2SD,MAX	<MAX
201	SODIUM	<MEAN + 2SD,MAX	<MAX
200	STRONTIUM	>MEAN + 2SD,MAX	>MAX
201	STRONTIUM	>MEAN + 2SD,MAX	<MAX
200	THALLIUM	ND	ND
201	THALLIUM	ND	ND
200	TIN	<MEAN,MAX	<MAX
201	TIN	ND	ND
200	URANIUM-233/234	<MEAN,MAX	NA
201	URANIUM -233/234	<MEAN,MAX	NA
200	URANIUM -235	<MEAN,MAX	NA
201	URANIUM -235	<MEAN + 2SD,>MAX	NA
200	URANIUM -238	<MEAN,MAX	NA
201	URANIUM -238	<MEAN + 2SD,>MAX	NA
200	VANADIUM	<MEAN + 2SD,MAX	>MAX
201	VANADIUM	ND	ND
200	ZINC	<MEAN + 2SD,MAX	<MAX
201	ZINC	<MEAN,MAX	<MAX

Notes:

IHSS = Individual Hazardous Substance Site.
< MEAN = OU 3 mean value is less than background or benchmark mean value.
> MEAN = OU 3 mean value is greater than background or benchmark mean value.
<MAX = maximum value.
<MAX = OU 3 Maximum value is less than background or benchmark maximum value.
>MAX = OU 3 Maximum value is greater than background or benchmark maximum value.
<MEAN, MAX = OU 3 mean and maximum values are less than background or benchmark mean and maximum values.
>MEAN, MAX = OU 3 mean and maximum values are greater than background or benchmark mean and maximum values.

MEAN + 2SD = Upper-bound background mean (i.e., mean plus two standard deviations).
TSS = Total suspended solids.
Column 1: IHSS 200: Great Western Reservoir; IHSS 201: Standley Lake
Column 3: Comparison of OU 3 groundwater data to Background Geochemical Characterization Report. IHSS 200 compared to upper flow regime and IHSS 201 compared to lower flow regime
Column 4: Comparison of OU 3 groundwater data to benchmark lake data.

4.6.3 Groundwater Summary

Groundwater analysis indicate that plutonium-239, -240 is not migrating from the reservoir sediments to the groundwater system within OU 3. Based on a qualitative comparison to background groundwater data, potassium and strontium are the only constituents with concentrations that exceed background levels in Well 49192. No constituents exceed background levels in Well 49292. No COCs were identified for OU 3 groundwater. In addition, the groundwater pathway is not a complete pathway from a human health exposure standpoint.

4.7 AIR EVALUATION

As discussed in Section 2.5, data from the ultra high-volume air sampling effort are not available at this time. It is anticipated that approximately 6 months of air monitoring data will be evaluated for the Final RFI/RI report.

In addition to the air sampling, wind tunnel studies were conducted in OU 3 to measure resuspension of particulates from soil. The studies were designed to address particle size distributions relative to wind speed, and activities of suspended radionuclides by particle size (DOE, 1992a). COCs were not selected specifically for air. The analytes selected as COCs for soil (plutonium-239, -240 and americium -241) are also considered COCs for airborne particulates. Data from wind tunnel studies in combination with surface soil data are used in the HHRA to evaluate exposure by the inhalation (air) pathway. Air-monitoring data collected through the Radionuclide Ambient Air Monitoring Program (RAAMP) are used to benchmark estimated ambient radionuclide activities based on the data from wind tunnel studies.

4.7.1 Rocky Flats Ambient Air Monitoring

Ambient air monitoring is performed for both nonradioactive and radioactive parameters. The most recent available ambient air monitoring data (i.e., 1993) are provided in the *Site Environmental Report* (DOE, 1994a). These data are summarized in the following two subsections.

Nonradioactive Ambient Air Monitoring

Nonradioactive ambient air monitoring is conducted for respirable particulate matter (e.g., particulate matter less than 10 microns in size, PM-10) and TSP. Samplers are located in unobstructed areas generally downwind from plant facilities.

The observed 24-hour maximum for the TSP sampler in 1993 was 90.0 milligrams per cubic meter (mg/m^3), which was 35 percent of the former TSP 24-hour primary standard. The annual geometric mean value was 48.6 mg/m^3, which was 65 percent of the former TSP primary annual geometric mean standard. The highest PM-10 value recorded (24-hour sample) was 51.9 mg/m^3 (34.6 percent of the primary standard). The annual arithmetic mean was 15.9 micrograms per cubic meter ($\mu g/m^3$), which was 31.8 percent of the primary annual arithmetic mean standard.

Radioactive Ambient Air Monitoring

Ambient air samplers monitor airborne dispersion of radioactive materials from Rocky Flats into the surrounding environment. The ambient air samplers are situated at Rocky Flats (21 locations), around the site boundaries (14 locations), and in neighboring communities (11 locations) (Figure 2-10). The overall mean plutonium activity from Rocky Flats samplers was 0.056 x 10^{-15} millicuries per milliliter (mCi/ml). Perimeter samplers measured a mean plutonium activity of 0.002 x 10^{-15} mCi/ml. The overall mean plutonium activity for community samplers was 0.001 x 10^{-15} mCi/ml.

4.7.2 Wind Tunnel Study

Portable wind tunnel tests (MRI, 1994) were conducted to quantify wind resuspension emissions of particulate matter from the soils and sediments of OU 3. Midwest Research Institute (MRI), performed testing on the shores around Standley Reservoir and Great Western Reservoir and on the terrestrial area between the two reservoirs.

An MRI portable pull-through wind tunnel was used in performing the field studies. Air was drawn through the tunnel at controlled velocities over the surface to be tested and sampled through a probe in the tunnel. This method enabled the exploration of the wind erosion process on specific test surfaces over a wide range of wind speeds. After placing the tunnel over the target surface, airflow was gradually increased up to the wind erosion threshold velocity and then reduced slightly. Wind erosion was measured by observing migration of coarse particles. At the sub-threshold flow, a wind speed profile was measured and a roughness height was determined. After sampling was completed, collected dust emissions were sent to an environmentally-controlled laboratory for gravimetric analysis. Screening and comprehensive tests were performed to (a) bracket the worst-case erodibility of representative portions of the study area with different surface characteristics, and (b) to operate the wind tunnel at one-third and two-thirds of the range between the threshold velocity and the capacity of the wind tunnel, respectively. The second test allowed determination of erosion potential and the decay in emission rate.

Fifteen screening tests and 8 comprehensive test series were performed during two field trips to Standley and Great Western Reservoirs in June and July 1993. The highest threshold velocities were found on the vegetated terrestrial areas without any surface disturbance (velocities greater than 80 miles per hour at the 10-meter reference height) while the lowest threshold velocities were found at the highly disturbed shoreline areas. The most erodible surface was located at test location S-4 (Walnut Creek inlet to Great Western Reservoir), where a large area of silt lay on top of the rocky sediment present on the shoreline (Figure 2-10).

The recorded ratio of PM-10 emissions to total particulate matter was higher on the terrestrial surfaces than on the shoreline. In addition, the ratio tended to decrease with level of disturbance, indicating that the increase in the wind-generated total particulate matter was higher than the increase in PM-10 emissions when the surface was disturbed.

All of the surfaces and conditions tested exhibited a threshold velocity for dust resuspension. The threshold velocity is the velocity below which there is no dust resuspension. Table 4-8 summarizes location type, the 10-meter equivalent threshold velocities, and erosion potential.

Above the threshold velocity, all surfaces exhibit an increase in erosion potential with increasing wind speed. This increase was measured for three types of surfaces and is summarized in Table 4-8.

The samples collected from the wind tunnel were processed for radiochemical analysis. Sample analysis was difficult because many of the wind tunnel runs produced little or no resuspended material. Various size fractions and wind tunnel runs had to be combined in order to provide enough material for analysis. This was done in order to maximize the amount of information available from the samples. As summarized in Table 4-9, the results of the radiochemical analysis were compared to the results of the soil sampling from the same locations to obtain ratios of radionuclides in the resuspended material to radionuclides in the soil. Evaluation of these results indicates that the radionuclide activities in the resuspended particulated (PM-10 fraction) range from .5 to 7.6 times higher than *in situ* soil and sediment concentrations. It is likely that radionuclide activities in resuspended particulates may be higher than those of the overall soil, because adsorption is most effective on finer grained materials (clays) rather that coarser-grained material (sand). Fine grained material is preferentially transported as it is winnowed from the surface soils.

Evaluation of the threshold velocity and erosion potential derived from the wind tunnel study, indicates that over the vast majority of OU 3, resuspension is of surficial soils and sediments is extremely limited and occurs only rarely. This is supported by the consistency of plutonium activities in the soils over the years since the 903 Pad release.

Table 4-8
Wind Tunnel Results

Location Type	10-m threshold velocity (m/s)	Erosion Potential (g/m^2)
terrestrial undisturbed	56.0	NA(g/m^2)
terrestrial disturbed	42.5	$E = 0.00188(u\text{-}U_{th})^{1.375}$
terrestrial extra disturbed	18.6	$E = 0.0309\ (u\text{-}U_{th})^{1.5}$
sediment extra disturbed	13.2	$E = 1.0883 \times 10^{-5}\ (u\text{-}U_{th})^{4.08}$

Table 4-9
Resuspended Ratios

Site, Analyte, and Particle Size	Ratio of Analyte in Resuspended Material to Analyte in Soil Sample
terrestrial, Plutonium, <10 microns	4.1
terrestrial, Plutonium, >10 microns	1.5
terrestrial, Americium, <10 microns	7.6
terrestrial, Americium, >10 microns	2.3
sediment, Plutonium, <10 microns	2.4
sediment, Plutonium, >10 microns	0.4
sediment, Americium, <10 microns	0.5
sediment, Americium, >10 microns	3.1

5.0 CONTAMINANT FATE AND TRANSPORT

Section 4.0 presented the nature and extent of contamination present at OU 3, and the process for determining the COCs. The COC determination process is more fully described in TM 4 (DOE, 1994d). Through a process of data usability assessments, statistical evaluations, and weight-of-evidence evaluations, only two radionuclides (plutonium-239, -240 and americium-241) were determined to be COCs in two of the five OU 3 media (Table 5-1). The remaining chemicals were determined to be either within the background concentration ranges or insignificant from exposure and risk perspectives. In summary, plutonium-239, -240 and americium-241 were retained as COCs in OU 3 surface soils (IHSS 199), whereas plutonium-239, -240 was retained as a COC for surface sediments in Great Western Reservoir (IHSS 200). No COCs were identified for the subsurface-sediment, surface water, and groundwater media. Of the four IHSSs that compose OU 3, no COCs were identified in any media associated with Standley Lake (IHSS 201) or Mower Reservoir (IHSS 202). Table 5-1 summarizes the media and COCs for OU 3.

This section discusses the environmental fate and transport of only plutonium-239, -240 and americium-241 at OU 3, because, with the exception of these two radionuclides, all other chemicals were determined to be insignificant from the human and ecological risk perspectives.

5.1 POTENTIAL ROUTES OF MIGRATION

Fate and transport interpretations are based on the knowledge about source characteristics, site physical properties (such as geochemistry and hydrology), physical and chemical properties of the COCs, and plausible pathways for human exposure. To understand environmental fate and transport of contaminants at OU 3, the potential for migration of the COCs was determined and the human exposure pathways of these COCs were assessed.

The potential transport media in OU 3 include soil, air, sediment, surface water, groundwater, and biota. Because human activities can also influence the distribution of contaminants in OU 3, especially

Table 5-1
Media and COCs for OU 3

IHSS	Surface Soil	Surface Sediment	Subsurface Sediment	Surface Water	Groundwater
199-Contamination of soils	Plutonium-239, -240 Americium-241	NA	NA	NA	NA
200-Great Western Reservoir	NA	Plutonium-239, 240	--	--	--
201-Standley Lake	NA	--	--	--	--
202-Mower Reservoir	NA	--	--	--	--

Notes:

NA = Not applicable
-- = No COCs were identified

contaminants in surface soils, possible anthropogenic processes are also considered as transport pathways. Figure 5-1 summarizes the potential contaminant transport pathways for OU 3.

The following general processes potentially influence contaminant transport:

- Advection—the physical process of contaminant transport in solution (applicable to groundwater, this is not a significant consideration for OU 3)
- Adsorption—fixation of contaminants on soil particles by various molecular interactions, generally resulting in retardation or reduction in mobility
- Diffusion—movement of contaminants due to concentration gradients (not a significant consideration for OU 3)
- Dispersion—the mechanical process of mixing due to differences in the transport medium velocities (not a significant consideration for OU 3)
- Erosion—conveyance of dissolved and suspended contamination in surface-water runoff (not a significant consideration for OU 3)
- Particulate Resuspension—dislodging and entrainment of soil particles in air due to wind erosion (a significant consideration for land areas within OU 3)
- Solubility/leaching—dissolution of a contaminant in a liquid transport medium and subsequent infiltration in the lower soil layers potentially impacting the groundwater (not a significant consideration for OU 3)
- Transformation—the loss or degradation of contaminants due to chemical reactions or microbial activity (not a significant consideration for OU 3 because the COCs have relatively long half lives)
- Volatilization—transfer of contaminants from a solid/liquid medium into vapor phase (not a significant consideration for OU 3 because the COCs are not volatile).

The most significant transport pathway at OU 3 has been identified historically as the direct airborne movement (resuspension) of the contaminated soil (current and future exposure) and the exposed surface sediments (future exposure, if Great Western Reservoir is drained). Erosion of the contaminated soils may constitute another potential pathway. Adsorption and desorption of contaminants during conveyance by surface-water runoff are phenomena that may influence the eventual impact on the secondary or receiving medium.

Advection, diffusion, dispersion, erosion, adsorption/desorption, solubility/leaching, transformation, and volatilization are not significant transport processes for COCs in OU 3.

5.1.1 Quantification of Migration Pathways

The characteristics of transportation via resuspension of soil particles were estimated using a box model and the results of a field wind-tunnel study performed for OU 3 (MRI, 1994). The box model gives the

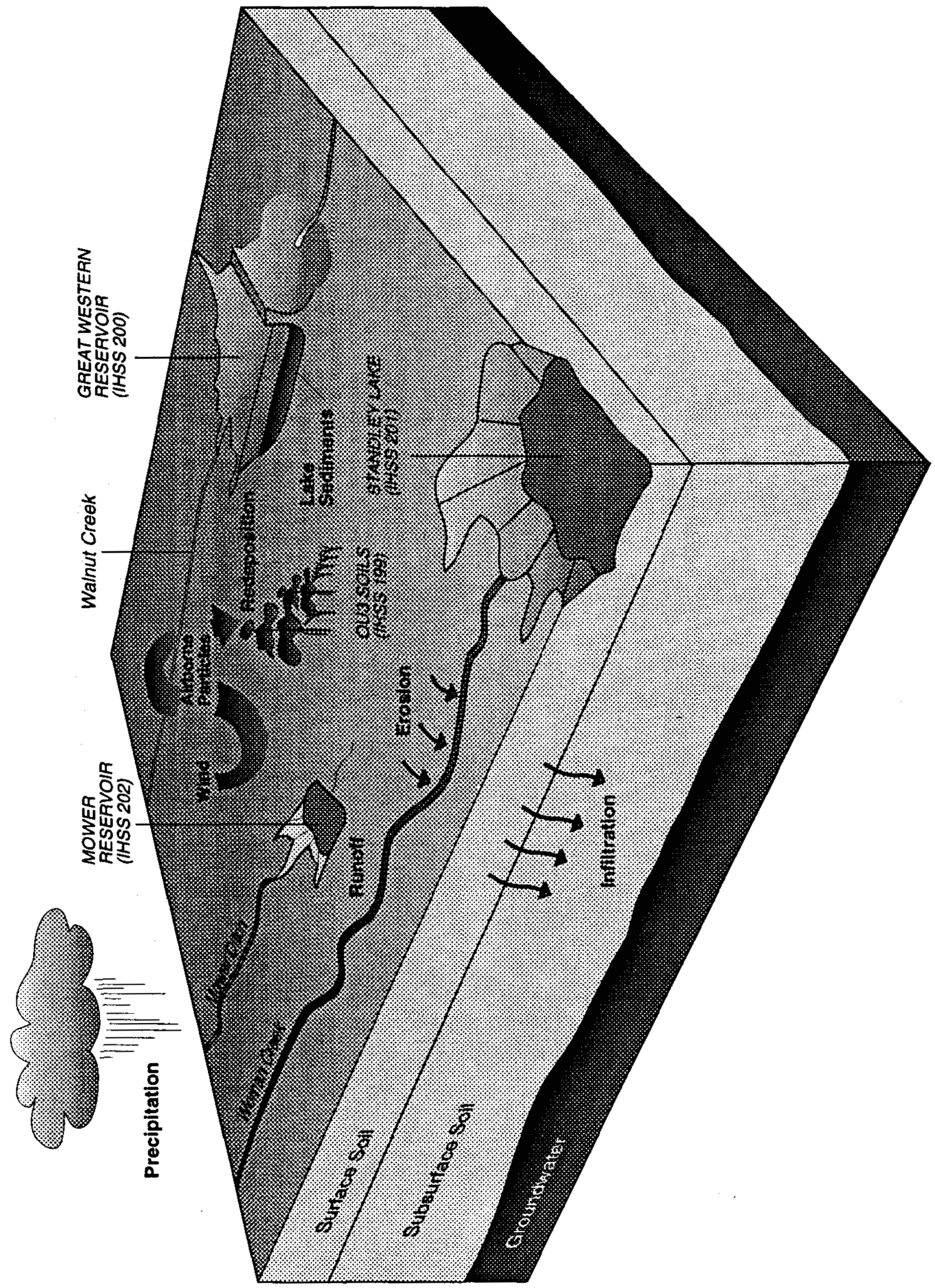


Figure 5-1 Potential Transport Pathways For OU 3

airborne exposure-point concentration for use in calculating the direct and indirect risks. The box model is discussed in Section 5.2.

A secondary transport process following particulate resuspension is the deposition of some of the particulates on ground and plant surfaces. This process is potentially important because of deposition of the particulates on edible vegetation. This vegetation could be ingested by both humans or grazing animals. The EPA's Fugitive Dust Model (FDM) was used to estimate the particulate deposition rate. FDM gives total deposition rate without distinguishing between dry and wet deposition rates. This should have no impact on the exposure-point concentrations, because wet deposition rate is generally insignificant (approximately 5 percent of the total). The FDM methodology and results are discussed later in this section.

Because no COCs were identified in surface water associated with OU 3 (Great Western Reservoir, Standley Lake, and Mower Reservoir), researchers concluded that erosion of surficial soils into surface water as well as resuspension of surficial soils with deposition is an insignificant contaminant transport mechanism with respect to the surface water. Similarly, it is concluded that infiltration is also an insignificant pathway because no COCs were identified for the groundwater medium. Therefore, fate and transport discussions relative to surface water and groundwater are not further pursued.

Although it is plausible to estimate by modeling (using a model such as the Modified Universal Soil Loss Equation [MUSLE]), the sediment loads and concentrations that result from watershed contributions to Great Western Reservoir, the actual sediment data from Great Western Reservoir sampling were used to evaluate exposure, in lieu of performing modeling. In the Environmental Assessment study for Standley Lake Diversion Project (DOE, 1992c), the MUSLE model was used for calculating the sediment loads entering Standley Lake from the Woman Creek watershed. The calculated sediment loads agreed with the representative yields calculated for the area by the U.S. Geological Survey (USGS, 1987). Therefore, no further modeling for OU 3 was deemed necessary.

The quantitative and qualitative discussions pertaining to the above migration pathways are presented later in Subsection 5.2. For contaminants at OU 3, physical transport pathways far outweigh chemical or biotic routes, in terms of dispersive properties. This disparity is because of the nature of the COCs.

5.1.2 Conceptual Site Model

Rocky Flats is considered the source of contamination to the soils (IHSS 199) and the reservoirs and drainages (IHSSs 200, 201, and 202) in OU 3. Based on information presented in the RFI/RI Work Plan (DOE, 1992a), the airborne, sediment, and surface-water pathways are considered the only reasonable migration pathways that could transport contamination from Rocky Flats to OU 3 soils, reservoirs, and drainages. A detailed discussion of the historical sources of contamination was presented in Sections 1.0 and 4.0 of this report.

Conceptual site models evaluating contaminant sources and releases, potential receptors, and associated exposures were presented in the OU 3 Work Plan (DOE, 1992a). These models identified the primary and secondary contaminant transport mechanisms. Migration routes include soil resuspension, soil erosion, and surface runoff.

The final Conceptual Site Model (CSM) for OU 3 is based on the RFI/RI results and depicts the significant migration pathways identified above. The CSM is schematically represented in Figure 5-1.

5.2 TRANSPORT PROCESSES IN OU 3 MEDIA

The mobility and persistence of contaminants within the environmental media at OU 3 are dependent on the physical and chemical characteristics of the individual contaminants and their interaction with the corresponding environmental medium.

5.2.1 Soil and Sediment Resuspension Pathway

Direct airborne movement of exposed surface soil and dry sediments is a primary migration pathway for OU 3, either by uplift or particle impact. Particle movement may be initiated through the impact of airborne particles with particles on the ground. The direct action of air moving past a particle may exert enough force to accelerate the particle, causing it to roll along the surface or be lifted up and moved in the air stream.

Particles dislodged from the surface can move in one of three ways:

1. Suspension: occurs when upward wind eddies counteract free fall, allowing transport of the particle at average wind speed. These particles are generally less than 0.1 mm in diameter and are redeposited by rain or gravity after the wind subsides.

2. Saltation: occurs when particles between 0.1 and 0.5 mm in diameter move by a series of short bounces. This is the most common method of migration.

3. Surface creep: occurs when particles between 0.5 and 3 mm in diameter roll or slide along the surface.

Many factors influence particle adhesion to a surface including: particle material composition, size, shape, surface roughness, relative humidity, presence of electrostatic charges, and other physical characteristics of the substrate. The amount of material carried in the air stream is a function of particle density, wind velocity, and the viscosity of the air. Primary meteorological factors that affect resuspension include wind velocity, ground surface moisture, and vegetation.

Reservoir levels fluctuate seasonally, with shallow water and shoreline areas the most susceptible to drying and possible resuspension. These exposed surface areas are made up of a crusty, plate-like surface (agglomeration of clays and partial cementation by calcium carbonate) that would require pulverization, in order for the sediments to become airborne. It is conceivable that vehicular or construction equipment traffic could cause this disintegration. If water levels remain low in the reservoirs for long periods, weathering could also eventually degrade the surface and provide an opportunity for resuspension.

The climate in the area of Rocky Flats and OU 3 is typified by strong, gusty winds that redeposit most suspended soil particles. High winds and other disturbances result in a greater area of dispersion and can cause particles to remain airborne longer. The dominant winds blow from the west and northwest, and occur more frequently during the winter months.

Once suspended in air, soil particles can move long distances depending on wind velocity and turbulence. Larger particles settle rapidly, whereas smaller diameter particles will be carried longer distances; therefore, the size of suspended soil particles is critical in assessing contaminant mobility. The respirable percentage of suspended contaminated soil particles with diameters less than 10 micrometers has been estimated to be approximately 20 to 40 percent. Because of the low settling velocities of such small particles, particles can be airborne for relatively long distances before settling.

Based on the knowledge that the radionuclide contamination in OU 3 originated from airborne dispersion and deposition of plutonium and americium from Rocky Flats, it is likely that the radionuclide activities in the resuspended particulates may be higher than those of the overall soil, because adsorption is most effective on finer-grained particulates (clays) rather than coarser-grained particulates (sands). The winnowing of the surface soil preferentially transport the finer grained particles. Evaluation of data from the wind-tunnel study indicates that the radionuclide activities in the resuspended particulates (PM-10 fraction) range from 0.5 to 7.6 times higher than *in situ* soil and sediment concentrations. This may have a significant bearing on estimating exposure via direct pathways (such as inhalation) and indirect pathways (such as deposition on above-ground vegetation, subsequent ingestion of the vegetation by humans and animals, and ingestion of contaminated dairy and animal tissue products by humans). However, redeposition of particulates on the bare soil surface is considered to have an insignificant impact on direct pathways (such as ingestion of soil) and indirect pathways (plant uptake through roots and subsequent intake of below-ground root vegetation by humans and animals) because the redeposited volume is thought to be very small and would have a negligible contribution to the existing soil. Within the bounds of modeled estimates and risk calculations, the radionuclide activities in the modified soil would not be distinguishable from those of the original soil.

Wind-Tunnel Study

Wind-tunnel tests performed by Midwest Research Institute (MRI, 1994) quantified resuspension emissions of particulate matter from soils and sediments in OU 3. Test sites included shores around Standley Lake and Great Western Reservoir, and terrestrial sites between the two reservoirs. An MRI portable pull-through wind tunnel was placed directly on the selected test site surface to collect resuspended soil and sediment. The wind tunnel airflow rate was gradually increased until visual erosion of the test surface occurred, as seen by resuspended particles. This flow rate was designated as the "threshold" flow rate for the specific test site surface. Two types of tests were performed in this study: screening tests and comprehensive tests. The screening test was performed at each test site to determine the worst-case erodibility of representative portions of the study area with different surface characteristics. The screening test entailed an emission measurement for a 20-minute sampling period with the wind tunnel operating near its flow capacity (40 miles per hour). During the comprehensive tests, the wind tunnel was operated at two flow rates: approximately one-third and two-thirds of the range between the threshold velocity (for the specific test surface) and the capacity of the wind tunnel. At each flow rate, a 2-minute test was followed by an 8-minute test to determine the decay in the emission rate and to calculate the erosion potential for the specific test surface.

Test sites were distinguished by three test conditions: undisturbed, disturbed, and extra disturbed. Undisturbed tests were performed on sites in their natural condition. Disturbed shoreline sites were raked to a depth of 1 to 2 inches to loosen any crust on the surface. Disturbed terrestrial sites had the vegetation cut at ground level, removed, and then the surface was raked to a depth of 1 to 2 inches. The extra disturbed tests involved the same activities, but also had a vehicle drive over the surface to pulverize the surface material (MRI 1994).

Thirty-two individual tests were performed. Raw test data included:

- Site code and description
- Test date, run number, and test type

- Start time and sampling duration
- Threshold wind speed at tunnel centerline
- Subthreshold wind-speed profile
- Operating wind speeds at tunnel centerline and at centerline of sampling tube
- Sampling module flow rate
- Ambient meteorology

As expected, the highest threshold velocities were seen at the undisturbed vegetated terrestrial sites, whereas the lowest threshold velocities were found at the disturbed shoreline areas, particularly the Walnut Creek inlet at Great Western Reservoir (MRI, 1994).

As discussed in Section 4.7.2, the wind-tunnel data were used to calculate erosion potential equations and emission rates for resuspended particulates. The emission rates were then incorporated into a box model to derive the particulate exposure-point concentrations for the HHRA as described below.

Box Model

Two areas in IHSSs 199 and 200, one of 10 acres and one of 50 acres, were modeled as square areas with wind-speed-dependent emission rates into the "box" of air space above the area. The model was designed to compute the equilibrium concentration of particulates in the boxes corresponding to the two areas. The governing equation of this box model is

$$LWH\frac{dC}{dt} = q_sLW + WHuC_{in} - WHuC \qquad (5\text{-}1)$$

where

L	=	Length of emission area (m)
W	=	Width of emission area (m)
H	=	Mixing height (m)
C	=	Airshed pollutant concentration (g/m^3)
C_{in}	=	Incoming concentration
u	=	Average diluting wind speed (m/s)
q_s	=	emission rate (g/m^2/s)

Steady-state solutions can be approximated by setting dC/dt = 0 and assuming that C_{in} = 0, representing clean, incoming air. This gives

$$C = \frac{q_sL}{uH} \qquad (5\text{-}2)$$

This equilibrium approximation is neither time nor width dependent.

The length and width of the airsheds are equal because the airsheds are specified as square areas, and a mixing height of 2 meters was used. The emission rate q_s was derived from the OU 3 Wind-Tunnel Study,where u_{th} is the threshold wind speed of 18.6 m/s at 10 meters, and the 900 seconds corresponds to

$$\frac{0.0309}{900}(u - u_{th})^{1.5} \qquad (5\text{-}3)$$

the model computing concentrations for the box for the 15-minute (900-second) blocks that have recorded averages above the threshold speeds.

The model operation involved importing an ASCII file containing the day, time, and wind speed data (measured at 10 meters above ground level) for all events above the threshold wind speed of 18.6 m/s. Because the relationship for q_s was developed for data measured at 10 meters, the u value is taken directly from the ASCII file. However, the diluting wind speed, u, is 12.01 m/s, which is the 1-meter equivalent of 18.6 m/s reduced from 10 meters. Once this ASCII file is imported into an appropriate spreadsheet, the equilibrium concentration equation can be input and applied to the applicable wind speed events.

The model was then run to obtain estimates for particulate concentrations in the box. The time of replenishment of soil available for resuspension was assumed to be 24 hours. Therefore, if a particular day has several 15-minute data blocks above the threshold, only the highest data block for that day is considered for resuspension. For example, given that a day has more than one data block above the threshold, the greatest wind speed that occurred that day will be applied to the emission rate equation for 15 minutes. The model computed the particulate concentration for a maximum of one event per day. A summary of parameters used in the box model is presented in Table 5-2.

Particulate concentrations (PM-10 fraction) were calculated for the 10- and 50-acre exposure areas in IHSS 199 (soils) and IHSS 200 (Great Western Reservoir sediments) using the box model. The particulate concentrations for these exposure areas are as follows:

- 2.65×10^{-4} mg/m^3 for IHSS 199, 10-acre exposure area (residential scenario)
- 5.90×10^{-4} mg/m^3 for IHSS 199, 50-acre exposure area (recreational scenario)
- 2.00×10^{-4} mg/m^3 for IHSS 200, 10-acre exposure area (residential scenario)
- 4.5×10^{-4} mg/m^3 for IHSS 200, 50-acre exposure area (recreational scenario)

These particulate concentrations were used in the HHRA to estimate levels of COCs in air to evaluate risk from the inhalation exposure route.

Table 5-2
Parameter Summary for Box Model

Parameter	Value	Data Source
Fraction of suspended particulates less than 10 m (F)	1.0	MRI Wind-Tunnel Study
Distance of emission (D)	200 m-residential 450 m-recreational	Based on square 10- and 50-acre exposure areas
Mixing height (L)	2 m	Standard default value
Area emission rate (ER)	$ER = 0.0309/900(u—u_{th})^{1.5}$	MRI Wind-Tunnel Study
Wind speed (U)	12.01 m/s	1-m equivalent of 10-m threshold speed of 18.6 m/s

Fugitive Dust Model

The FDM was used in conjunction with the wind-tunnel results to predict plutonium concentrations in air at OU 3 based on transport of particulates from areas at Rocky Flats and OU 3. The FDM allows for the use of area sources for dust resuspension. To determine the appropriate areas for modeling resuspension, soil-sample data for Rocky Flats and OU 3 were used to develop isopleths. Isopleths were developed for the following soil activities: 0.5, 1.0, 5.0, 10.0, 25.0, and 40.0 pCi/g. From these isopleths, areas for modeling were developed between the isopleths. A total of six areas were developed for modeling: 0.5 to 1.0, 1.0 to 5.0, 5.0 to 10.0, 10.0 to 25.0, and 25.0 to 40.0, and greater than 40 pCi/g. Each of these areas was then divided into approximately one-hundred squares of equal size. The coordinates and size of each square in each area were then entered into the FDM as sources.

The receptors used for the FDM were a grid of points covering OU 3. Dust concentrations were modeled for approximately 100 receptor points. The meterological data used for the FDM were site-specific data taken from the 10-m level of the 61-m tower located in the site's west buffer zone. These data were one-hour averages of the raw data from the tower.

The FDM requires a threshold velocity and wind-speed-dependent emission rate as input parameters. The values used in the FDM runs for OU 3 were derived from the wind-tunnel study; specifically, a threshold wind speed of 18.6 m (extra-disturbed terrestrial location).

The wind tunnel study was useful in defining the conditions necessary for resuspension to occur and developing the input parameters for the FDM modeling. However, it should be noted that the most common surface conditions in OU 3 are undisturbed terrestrial soils. As noted earlier in Section 4.0, the conditions necessary to resuspend vegetated and undisturbed terrestrial soils occur only sporadically and are relatively extreme. Undisturbed terrestrial soils have a threshold velocity of 56.0 m/s. Erosion potential was essentially not measurable. In order to provide any input parameters to the FDM model, numerous unrealistic and extremely conservative assumptions were required. The threshold velocity used is for an extradisturbed terrestrial location. That is one that has had vegetation removed, been raked, and driven over with a truck. In addition, the erosion potential for the extra disturbed site was used. It was also assumed that wind events capable of causing resuspension occur once every day and that the reservoir of contaminated soil is always available for resuspension. Using these extremely conservative assumptions, the results of the FDM model indicate that inhalation risk is extremely low (Figure 5-2 and 5-3).

Dust concentrations obtained from the FDM were converted to plutonium activities in air using the resuspension ratio for soil described in Subsection 2.5 (i.e., ratio of plutonium activity in resuspended material [PM-10 fraction] to plutonium activity in soil). Figures 5-2 and 5-3 show the inhalation risks for OU 3 based on modeled plutonium activities in air using source contributions from Rocky Flats and OU 3 for various years. The threshold wind speed and emission rate are for terrestrial, extra-disturbed conditions, and the 3600 represents the number of seconds in the meteorological time interval used (1 hour) and an emission rate of $E = 0.0309/3600\ (u-u_{th})^{1.5}$.

As a benchmark for the FDM results, the measured plutonium activity in air for one of the perimeter RAAMP samplers (S-37, Figure 1-3) was compared to the modeled plutonium activity for the same location. These two values were consistent with each other; the measured value was 7×10^{-6} pCi/m^3 (measured in 1990) and the modeled value was 6×10^{-6} pCi/m^3. These values are also consistent with the exposure-point concentrations derived from the box model for the 10-acre exposure-areas in

IHSS 199 (i.e., 3.21 x 10^{-6} to 7.03 x 10^{-6} pCi/m^3). These exposure-point concentrations are presented in the HHRA (Appendix A).

5.2.2 Surface Water and Sediment

Studies performed for the Environmental Assessment for the Standley Lake Diversion Project (SLDP) indicated relatively low erosion rates in the area of OU 3. Average sediment yields published by the USGS for the area range from 0.1 to 0.3 ton/acre/year (USGS, 1987). Suspended sediments settle to the bottom of stagnant surface water bodies which include reservoirs and other topographically confined areas. Surface water bodies may also receive sorbed contaminants through redepostition of small particles by wind action.

Streams in the vicinity of Rocky Flats are expected to be "erosional," meaning that they will tend to transport their full sediment loads downstream rather than permanently depositing them within the drainage. Water levels in the reservoirs fluctuate widely with varying supply and demand, particularly on a seasonal basis. Sediments in near-shore environments and other shallow water areas may be exposed for long enough periods to dry out. Dry stream beds and exposed reservoir sediments are potentially subject to a similar set of release and transport mechanisms (see Subsection 5.2.1).

As stated earlier, no sediment or surface water modeling was specifically performed for OU 3, because analysis of sediment and surface-water samples supplied actual data. These samples were collected during the course of the OU 3 RFI/RI, and the sample data were used as exposure-point concentrations for applicable pathways.

In 1990, Colorado Congressman David Skaggs organized a committee to develop and evaluate surface water management options for the Woman Creek and Walnut Creek drainages to protect existing drinking water supplies immediately downstream of Rocky Flats (i.e., Standley Lake and Great Western Reservoir). The committee recommended and approved the Option B plan, which has two major components:

- Construction of facilities primarily in the Woman Creek Basin to detain and divert surface water flows that may be influenced by Rocky Flats activities away from Standley Lake (Standley Lake Protection Project).

- Replacement of the City of Broomfield's Great Western Reservoir as a drinking water supply with an equivalent drinking water supply (Great Western Reservoir Replacement Project).

A brief summary of the two major components of Option B is provided below. Additional summary information concerning the Option B plan is presented in Section 1.3.7 of this report.

The Standley Lake Protection Project (SLPP) will use a detention reservoir (Woman Creek Reservoir) and other associated surface water management features that will physically isolate Standley Lake from Woman Creek, which currently conveys runoff from Rocky Flats to Standley Lake. The 850 acre-feet detention reservoir will be constructed to contain a 100-year flood, 24-hour event. The surface water management facilities will divert and temporarily store runoff from Woman Creek so that it can be tested for possible contaminants. If the water does not meet applicable water quality requirements, it will be retained for appropriate action prior to release. After verification that the water meets applicable water quality standards, the water will be pumped to Walnut Creek, just downstream of Great Western Reservoir, for downstream beneficial use. Construction of Woman Creek Reservoir began in April 1995 and is expected to be completed by the end of 1995.

The SLPP will also incorporate provisions for long-term operations and maintenance. These provisions are described in the Operations Agreement between the cities serviced by Standley Lake (Westminster, Northglenn, and Thornton). The agreement document describes responsibilities and protocols for testing and treatment under normal streamflow and storm event conditions, as well as for potential spill events. The SLPP surface water management facilities will isolate Standley Lake from Woman Creek runoff and subsequently protect this drinking water supply from possible surface water contaminants originating from Rocky Flats.

The purpose of the Great Western Reservoir Project is to replace the drinking water supply provided by the Great Western Reservoir (GWR) system. The GWR system includes water rights, storage capacity, delivery systems, and water treatment capacity. The City of Broomfield completed its purchase of the "Windy Gap" water rights in 1993. This purchase of 4,300 acre-feet from the City of Boulder, combined with other Windy Gap water rights holdings, provides the City with 5,600 acre-feet of Windy Gap water that will be deliverable to Broomfield via a pipeline from Carter Lake, located near Loveland, Colorado. The raw-water pipeline is expected to reach Broomfield by the end of Summer 1995, with a delivery capacity of 12.4 cubic feet per second.

The City of Broomfield has completed construction of its terminal reservoir, located at the terminus of the raw-water pipeline, near West 144th Avenue and Lowell Boulevard. This 300 acre-feet capacity reservoir provides emergency storage adjacent to the City's new water treatment plant and will replace GWR as the City's water supply reservoir. When the new water supply and delivery pipeline are in place, GWR will no longer be used as a municipal water supply. Future use of GWR is currently undefined. Broomfield residents are expected to begin receiving their water from Carter Lake via the raw-water pipeline in 1995.

As previously discussed in Section 1.3.2, the Broomfield Diversion Ditch (Great Western Reservoir Diversion Ditch) currently prevents surface water from Rocky Flats, when flowing through the north and south branches of Walnut Creek, from reaching GWR. The flows from Walnut Creek are treated at Rocky Flats and are diverted around GWR through the Broomfield Diversion Ditch into the drainage ditch below the GWR outlet.

Implementation of the Option B surface water management components discussed above are designed to prevent future transport of potential Rocky Flats contaminants in surface water flows to downstream municipal drinking water supplies. These facilities should be considered when risk management decisions are made.

5.2.3 Biotic Processes

Contaminants can be taken up from surface soils by biota either through mechanical spreading (tracking) or through physical incorporation into the biomass. Biota may be exposed to contaminants by ingestion, inhalation, or contact with contaminated soils, sediments, or surface water. Bioaccumulation or biomagnification is characterized by an increase in contaminant concentrations in biological tissues in successive members of a food chain and may result in progressively higher contaminant concentrations up the food chain. Tracking is considered an insignificant release mechanism when compared to the potential for wind or water erosion from surface soils.

Contaminants eroded from surface soils by wind or water may settle onto foliar surfaces of vegetation. The magnitude of foliar retention will depend on the physical structure of the surface. Foliar contamination can migrate by resuspension, rainfall, wind, and plant decomposition. Contaminants that settle on foliar surfaces or physically adsorb to the surfaces of plants can be transmitted through the food chain or absorbed metabolically by plants.

Based on volume, biota are not considered a significant contaminant transport pathway for OU 3. Potential contamination in biota and contaminant behavior in the food web is discussed in the Appendix B.

5.3 FATE OF CONTAMINANTS

Subsection 5.1 summarized the potential complete contaminant migration routes at OU 3. A detailed discussion of the transport processes for the identified migration routes was presented in Subsection 5.2. This section focuses on chemical and physical behavior of the contaminants plutonium-239, -240 and americium-241, and media characteristics that influence the contaminant mobility and fate.

5.3.1 Contaminant Behavior

The mobility and distribution of contaminants at OU 3 was evaluated by considering the chemical and physical interactions between a contaminant and its corresponding environmental media. Generally, these contaminant radionuclides of concern adsorb strongly to soil particles (especially clay, metal oxides, and organic matter), due to their high soil distribution coefficients and limited solubility. These interactions determine probable fate and transport processes operating at Rocky Flats and OU 3. The magnitude of each contaminant transport process is measured in terms of rate and volume. Each transport process is potentially affected by release mechanisms or other contaminant fate processes that increase or decrease the rate or amount of contaminant available for transport. Relevant contaminant fate processes at OU 3 include, but are not limited to, (1) radioactive decay, (2) adsorption reactions, (3) oxidation/reduction reactions, (4) complexation reactions, (5) precipitation and dissolution, and (6) biouptake. The effects of these processes and the physical and chemical properties of the media and contaminants are discussed below.

5.3.2 Physical and Chemical Properties of the OU 3 Media

Impact of Soil Clay Content

Migration to groundwater was not identified as a transport route. Information about soil clay content in OU 3 supports the exclusion of this migration route. The soils in the area are characterized by a high content of swelling clays underneath the topsoil and gravel layers. Clays are negatively charged and have a very large surface area. In the presence of soil moisture, plutonium and americium have a tendency to preferentially adsorb to clay through ion-exchange mechanisms.

Organic Carbon Content

Organic carbon content of the solid media (soil/sediment) has a great influence on the mobility of radionuclides through these media. The radionuclide COCs have relatively high soil distribution coefficients implying that the mobility of the COCs would be retarded with increasing organic carbon content. Total organic carbon (TOC) measurements were performed for subsurface OU 3 soils during the RFI/RI study. TOC ranged from 2 to 5 percent in the A horizon of the soil trenches (approximately 0- to

12-cm depth ranges). TOC levels in deeper horizons were lower than those in the A horizon, as expected. Appendix H contains data for all horizons for each trench. TOC measurements were also made on the sediment samples. The TOC concentrations in sediments ranged from nondetect values (less than 0.05 percent) to 2.7 percent in sediment grab samples. The sitewide average was 0.52 percent for 28 samples with a deviation of 0.56 percent. TOC was not detected in four sediment samples, whereas all but three samples measured less than 1.0 percent TOC concentration. The values from TOC content suggest that mobility of plutonium in soils and sediments may be retarded by the organic carbon present.

Several field studies (Baes and Sharp, 1983) indicate that the soil distribution coefficient, K_d, for plutonium ranges from 12,000 to 130,000, depending on the organic carbon content. This implies that, at equilibrium, the soil plutonium concentration would be a factor of 12,000 to 130,000 higher than the water concentration. Studies performed on agricultural soils indicate K_d values as high as to 300,000 for plutonium (Baes and Sharp, 1983). Positively charged inorganic species typically adsorb to negatively charged clays and other fine-grained particulates rather than organics. Organics play a small and relatively insignificant role in the transport of plutonium. Based on these data, it is expected that plutonium would preferentially adsorb to the sediment particles rather than partitioning to the aqueous phase. Thus, transfer of plutonium from sediments to the aqueous phase is not anticipated. Literature K_d values for americium range from 1 to 47,000 (Baes and Sharp, 1983). The details of the field studies are not known; however, it is expected that americium would also exhibit very low mobility from sediments and into solution.

5.3.3 Physical and Chemical Properties of Plutonium and Americium in OU 3

Radioactive Decay

The measure of radioactive decay is the half-life, which is the constant time period required for half of the atoms in a radioactive substance to disintegrate. Radioactive decay occurs spontaneously and independently of all external physical and chemical influences. Almost all decaying radionuclides, including the ones analyzed at Rocky Flats, lead to formation of other elements. For example, spontaneous beta-disintegration of plutonium leads to the formation of americium. Sometimes these decay products (daughters) will be unstable and radioactive, similar to their parent elements.

Adsorption

Adsorption is the physical and/or chemical process by which a substance is accumulated at an interface between phases. Adsorption processes are surficial reactions that involve inorganic solids such as clays and iron oxyhydroxides or organic carbon transferring a radionuclide from the aqueous phase to the solid phase. In general, radionuclide adsorption increases with increasing clay, iron oxyhydroxide, and organic carbon content. The principles that govern adsorption in nature are much the same as those frequently used in wastewater treatment schemes. Electrostatic forces are the primary physical and chemical basis behind adsorption bonds. Other forces that bind molecules to each other include dipole-dipole interactions, hydrogen bonding, hydrophobic bonding, etc. Plutonium and americium have a strong affinity to bond to the surfaces of soil particles, thus explaining the primary pathway of eolian transport and the lack of migration to lower soil layers (Montgomery, 1985).

Oxidation and Reduction Reactions

Chemical reactions that involve the exchange of electrons are known as oxidation-reduction, or redox, reactions. Redox reactions are relevant, in that they influence the mobility of redox-sensitive (multivalent) species. Mechanisms of redox reactions may determine the nature and transport of the contaminants as well as the reaction rate.

Oxidizing or reducing environments are functions of the redox potential (Eh), and determine the likelihood of a species to lose or gain electrons. The oxidation potential of a system is important in assessing contaminant fate and transport pathways. The oxidation state of multivalent metals and radionuclides can determine the solubility and mobility of the element and, in some cases, its toxicity. For example, trivalent plutonium, Pu(III), is more mobile than Pu(IV), which forms the highly insoluble oxide, PuO_2. Therefore, reducing conditions favor mobility and oxidizing conditions (surfaces exposed to atmosphere) decrease mobility of plutonium.

Complexation Reactions

Complexation reactions refer to the formation of aqueous complexes between metal ions and complexing agents. Complexation of an element can alter many of the chemical properties of the species, including solubility, attenuation behavior in soils, bioconcentration factors, and toxicity (Bodek, 1988).

Generally, complexation will increase the apparent solubility of an element, and the complexed ions may not adsorb to mineral surfaces. Thus, aqueous complexation may increase overall mobility of contaminants (Rai and Zachara, 1984).

Precipitation and Dissolution

Equilibrium solution chemistry can be used to estimate the maximum concentrations of solubilized radionuclides. These calculations use thermodynamic solubility constants of solid phases that are formed by and with the radionuclides. If the concentrations of dissolved species exceed the solubility limit of a mineral phase, precipitation can be expected. Inversely, if the solubility limit is not exceeded, dissolution may be expected. In natural systems, many factors complicate the application of the chemical equilibrium principles. If the kinetics of mineral precipitation are too slow, the aqueous phase may become oversaturated. Temperature, solution composition, Eh, and pH also have a significant influence on precipitation and dissolution.

Precipitation/dissolution is more applicable to groundwater than surface water, because generally an equilibrium can be expected due to slow movement of solutions through the aquifer. In contrast, contaminant migration through surface water is a dynamic situation, in which a chemical equilibrium cannot be expected. The physical aspects of surface-water flow (volume, velocity, contact time, etc.) may result in contaminant concentrations that are several factors or orders-of-magnitude below the solubility limits. Furthermore, plutonium and americium have very limited solubility in water at the near-neutral pH expected for surface-water runoff. This is confirmed by the very low radionuclide concentrations measured in the OU 3 surface-water bodies (Great Western Reservoir, Standley Lake and Mower Reservoir). Surface waters within OU 3 were not identified as media of concern.

Biouptake

The uptake of inorganics is a natural cycle in plants and animals. For plants, pathways can involve both surface contact and root uptake. Exposure to animals may occur in several different ways, including ingestion of contaminated vegetation, surface water, and soil. Bioaccumulation, the degree to which an organism accumulates a specific chemical from the environment, results from ingestion of contaminants in food or exposure to abiotic media. Through this process, contaminants can reach toxic levels in higher level organisms, when they are at low, relatively nontoxic levels in abiotic media (Bodek, 1988). The "concentration factor" may be defined as the measure of accumulated contamination within an organism, or, Concentration of Substance in Organism (wt/wt)/Concentration of Substance in Soil or Water (wt/wt or wt/vol).

Analyzing biouptake processes enables identification of transport pathways to susceptible receptors. There are no generally applicable mathematical techniques for estimating the extent of biological concentrations of inorganics, even for combinations of chemicals and biological species known to result in bioaccumulation. This is primarily because the biological uptake of inorganics is entirely situation-specific, depending on combinations of many factors that affect environmental availability and fate within the organism (Bodek, 1988).

5.3.4 Fate and Transport Properties of Radionuclides

The geochemistry and mobility of radionuclides in soil-water systems is controlled by a variety of chemical processes including, but not limited to, adsorption, ion exchange, complexation, precipitation, and oxidation/reduction reactions (Brookins, 1988). Published soil-water distribution coefficients, in conjunction with known OU 3 soil properties (i.e., clay content, soil Eh and pH, and organic carbon content), can be used to derive qualitative estimates of radionuclide transport in soils. The published distribution coefficients for radionuclides are presented in Table 5-3. The distribution coefficients are considered empirical and strongly influenced by site environmental conditions. The solubility and radioactivity measurements of a radionuclide are equally important in evaluating mobility of a chemical. The following subsection presents specific fate and transport discussions for plutonium. The discussion focuses on plutonium, because plutonium has been documented as the primary contaminant of concern for OU 3.

Plutonium

Plutonium is a transuranic radioactive element produced by fission reactions in nuclear reactors, by the explosion of nuclear fission devices, and by natural radioactive processes. There are 15 isotopes of plutonium-239, with half-lives ranging from minutes to thousands of years. The principal isotope, plutonium-239, has a half-life of 24,400 years and a specific activity of 6.13 x 10^{10} pCi/g. Small amounts of plutonium-239 are produced naturally in uranium minerals, such as pitchblende and carnotite, and by neutron capture of uranium-238 followed by beta decay of the resulting uranium-239 and Neon-239 (Faure 1991).

Plutonium is stable in two oxidation states in most natural environments as Pu^{+3} and Pu^{+4}. Pu(III) is the dominant species in reducing environments, whereas Pu(IV) is the dominant species under oxidizing conditions, such as in OU 3. Under typical environmental conditions (pH 5 to 8 and Eh > 0.05 volts) (Brownlow, 1979), Pu will most likely be found speciated, with $Pu^{+4} > PuO2^{+2} > Pu^{+3} > PuO^{+1}$ (Ames and Rai, 1976). The most probable species of plutonium is the $^{+4}$ oxidation state, which forms PuO_2 (plutonium dioxide) or Pu $(OH)_4$ (plutonium hydroxide) (Brookins and Dragun, 1988). This assumes pH is not low and Eh > 0 volts (i.e., an oxidized system).

Plutonium has been detected above background in OU 3 soils and sediments. Plutonium tends to have geochemical characteristics that affect its mobility due to:

Table 5-3
Literature Distribution Coefficients for Radionuclides

Radionuclide	Representative Value[1]	Summary Range Low	Summary Range Maximum
Americium-241	700	0[4]	47,230[1]
Bismuth-214	200		
Cadmium-109	6.5	1.26[1]	50[3]
Cesium-143	850	3.0[4]	300,000[2]
Cesium-137	1,000	1.3[4]	52,000[1]
Cobalt-60	45	0.2[1]	23,624[4]
Lead Bismuth-212	900	4.5[1]	7,640[1]
Plutonium-238, -239, -240	4,500	0.4[4]	8.7E7[4]
Potassium-40	5.5	2.0[1]	9.0[1]
Radium-288	450	200[1]	467[4]
Strontium-90	35	0.15[1]	4,300[4]
Thorium-228	1,500	5[4]	1E6[4]
Uranium-234	1,500	0[1]	4,400[1]

1 U.S. Department of Energy, 1984. A review and Analysis of Parameters for Assessing Transport of Environmental Released Radionuclides through Agriculture.
2 U.S. Department of Energy, 1980b. Determination of Distribution Coefficients for Plutonium, range of results for a variety of sediments in the Enewetak Lagoon using Lab and Field experiments; Transuranic Elements in the Environment, Technical Information Center.
3 Coughtrey, P. J. and M. C. Thome, 1983. Radionuclide Distribution and Transport in Terrestrial and Aquatic ecosystems, A Compendium of Data.
4 ACS Symposium Series, 1979. Radioactive Waste in Geologic Storage (Abyssal Red Clay) Conc = 1E3-1E8 mg/atom/ml in 0.68N NaCl Soil Distributed Coefficient for CS pH2.7-8.0 Figure 1; for Cd pH 5.3 Figure 3; for Sr Phy.1-73; for Ba pH 2.6-8.3 Figure 2; for Ce pH 5.8-8.0 Figure 4.

- Resuspension and dispersion via wind and water while attached to a solid phase
- Low availability in soil attributed to rapid adsorption to clay, metal oxides, and organic matter
- Very limited downward movement in soil column via mass flow, diffusion, or mass transport
- Insignificant dissolution of plutonium in natural waters
- Low ecological mobility
- Insignificant transport via biological activity
- Physical transport mechanisms are more significant than chemical processes

Plutonium has a strong tendency to adsorb to clays, metal oxides, and organic matter resulting in a low migration potential (CSU, 1974; Brookins, 1984). The soil distribution coefficient for plutonium is high ($K_d = 10^3$ to 10^5 (Allard and Ryberg, 1983; Coughtrey, 1984) (see Table 5-3). When soluble Pu(IV) is added to relatively neutral soil, greater than 90 percent rapidly sorbs to clay particles (Coughtrey, 1984). Mobility is enhanced in highly reduced or highly oxidized soils and soils with low clay content. Experimental evidence indicates that it is extremely unlikely that more than 3 percent of added plutonium will remain as soluble chemical species in a soil-water solution; it is typically less than one percent (Coughtrey 1984).

Higher concentrations of plutonium generally exist in the surface soils rather than the subsurface soils in OU 3, because surface or near-surface conditions are oxidizing and near-neutral pH.

Plutonium as Pu(III) and Pu(IV) has very limited solubility in natural waters (Coughtrey, 1984). The presence of multiple oxidation states and irreversible reactions between them makes the prediction of long-term behavior of plutonium in aquatic systems difficult. The environmental behavior of plutonium is further complicated by the existence of ionic, particulate, and both colloidal and pseudo-colloidal plutonium in the water column. Less than 4 percent of plutonium introduced into water systems stays in solution; the remaining 96 percent sorbs to sediment particles (Coughtrey, 1984). The mean residence time in the water column is a function of availability of sediment particles, sedimentation rate, Eh, pH, and water depth.

The adsorption of plutonium on sediments is not fully reversible, due to colloid formation and changes in the oxidation state. It has been shown that Pu in the oxidized form shows less tendency toward adsorption compared to reduced forms. Surface water typically is characterized by oxidizing conditions and neutral or near-neutral pH. Under these conditions, plutonium will exist in the +4 oxidation state as plutonium oxide (PuO_2), or plutonium hydroxide [$Pu(OH)_4$]. However, density stratification of lake water in summer may result in a reducing environment in deeper water. Under reducing conditions, the K_d of plutonium may be 3- to 10-fold lower than typical reservoir conditions, resulting is a slight increase in plutonium mobility. However, the magnitude of this increase is not significant in terms of overall plutonium mobility (ANL, 1986).

Plutonium oxide is insoluble in water and will not tend to leach to groundwater, adsorbing to solids at pH 3 to 9 (Roxburgh, 1987). The solid phase of PuO_2 typically exits as a colloidal polymer of neutral or positive charge and can contain 10^6 to 10^{10} Pu atoms (Andelman and Rozzell 1970). Increasing the pH tends to reduce the charge density of the polymer and at pH > 9, the colloids can become negatively charged, decreasing the affinity for soils and potentially increasing the mobility in water. The pH of the groundwater in the OU 3 area is 7.5 (neutral to slightly basic), thus attributing to decreased mobility of plutonium.

Sorption to sediment particles is a function of ion-exchange reactions, precipitation and mineral formation, complexation and hydrolysis, oxidation and reduction reactions, and colloid and polymer formation. Concentrations in water may increase, as will the distribution coefficient. However, only approximately 5 percent is redispersed as radiocolloids or adsorbed onto dispersed colloidal sediment particles at a pH of 12. Rees, et al., (1978) maintains that migration of plutonium would be slow and difficult to remove from sediment layers by leaching.

Plutonium is not considered ecologically mobile (Coughtrey, 1984). Possessing no biological function, it can only be passively incorporated into organisms, mainly by physical processes such as surface contact, inhalation, or ingestion. Contamination of plants is a function of species, plant type, age of plant, pH, cation exchange capacity, and duration of contamination. The plant to soil partition coefficient by foliar and root contamination is 2×10^{-2} and by root contamination alone is 5×10^{-4} (Coughtrey, 1984).

Therefore, surface contamination of plants dominates over root uptake. Contamination of vegetation by resuspension of contaminated soil particles is more prevalent in arid, windy areas (Coughtrey, 1984).

Groundwater does not appear to be a viable transport medium for plutonium from OU 3 surface soils. Research and investigation of plutonium mobility at other locations have demonstrated that plutonium transport through unsaturated porous media is not significant (Andelman and Rozzell, 1970). The reasons for this immobility appear to be the insolubility of plutonium dioxide and the strength with which it adsorbs to fine-grained particles and organic matter in unsaturated porous media.

5.4 SUMMARY

The most significant transport pathway for OU 3 has been identified as the direct airborne movement (resuspension) of the contaminated soil (current and future exposure) and the exposed surface sediments (future exposure, if Great Western Reservoir is drained).

The box model and FDM results indicate that low levels of plutonium (approximately 6×10^{-6} pCi/m^3) in resuspended particulates are expected for areas in OU 3. The modeled results from both the box model and the FDM are consistent with data from one of the perimeter RAAMP samplers used to measure levels of plutonium in ambient air. The perimeter samplers are located directly west of OU 3, along Indiana Street.

6.0 SUMMARY OF BASELINE RISK ASSESSMENT

The Baseline Risk Assessment (BRA) for OU 3 includes a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment (ERA). These two components of the BRA are presented in Subsections 6.1 and 6.2, respectively.

6.1 HUMAN HEALTH RISK ASSESSMENT

This summary presents the results of the HHRA for OU 3. The complete HHRA report is presented in Appendix A.

The purpose of the HHRA is to assess the potential human health risk associated with OU 3 and to provide a basis for determining whether or not remedial actions are necessary.

The results of the HHRA show the human health risks are from residential exposure to plutonium-239, -240 and americium-241 in soils at location. The estimated cancer risk for this area is 3×10^{-6}. The other residential exposure risks range from 1×10^{-6} to 6×10^{-8} for the other soil source areas and sediments in Great Western Reservoir. These residential risks are within or below the EPA guidelines for the risk range protective of human health (1×10^{-4} to 1×10^{-6}).

The cancer risks based on a recreational exposure range from 5×10^{-8} to 8×10^{-10}. These cancer risks are well below the point of departure for remediation goals as stated in the National Contingency Plan.

6.1.1 Risk Assessment Approach

The objective of the risk assessment is to identify and estimate potential human health risks resulting from exposure to site contaminants present in various environmental media at OU 3. The HHRA evaluates radiological and nonradiological contaminants. Radiological contaminants are the major concern at OU 3. The EPA and DOE require a two-phase analysis for the radiological portion of the assessment. The HHRA incorporates the two-phase analysis, which includes:

- Procedures established by the International Commission on Radiological Protection (ICRP) and adopted by the EPA to estimate the radiation dose equivalent to humans from potential exposure to radionuclides through all pertinent exposure pathways.
- Estimates of health risk based on the age-averaged lifetime excess cancer incidence per unit intake (and per unit external exposure) for radionuclides of concern.

The HHRA results will be used to determine if remedial actions are warranted at OU 3, and if so, what associated cleanup levels will be necessary to protect human health.

6.1.2 Identification of Areas of Concern and Chemicals of Concern

Two separate but related data evaluation processes were used to identify areas of concern (AOCs) and chemicals of concern (COCs) specific to OU 3. The objectives of the processes include:

- For the AOCs, to identify "source areas" that, due to the nature and extent of contamination, warrant detailed evaluation in the HHRA.

- For the COCs, to identify potentially site-related chemicals (i.e., potentially related to historical releases from Rocky Flats and subsequent migration to OU 3) whose concentration or activities exceed background levels and whose presence may represent a significant impact on human health.

The conservative nature of the processes applied to the data ensure that the areas of OU 3 associated with the highest degree of potential risk are identified and evaluated in the HHRA. The data evaluation processes were applied to each IHSS individually because each is associated with unique characteristics related to the potential for chemical migration and potential for exposure. The following briefly describes each process and the individual results.

Areas of Concern

The AOCs for OU 3 were identified using the CDPHE Conservative Screen. The CDPHE Conservative Screen was developed for Rocky Flats by CDPHE, EPA, and DOE as part of the data aggregation process used in HHRAs. The CDPHE Conservative Screen includes the following six components in order of implementation:

- Define potential chemicals of concern (PCOCs). The PCOCs are defined as either inorganic analytes with concentrations or activities detected in OU 3 that are significantly elevated over background levels, or as organic analytes detected in OU 3 at concentrations greater than the detection limits reported in the Rocky Flats Environmental Database System (RFEDS).

- Identify "source areas." Source areas are defined as those areas of each IHSS within the OU where concentrations or activities of each PCOC exceed an upper-bound background value (i.e., background mean plus two standard deviations).

- Calculate a risk-based concentration (RBC) for each PCOC using default exposure assumptions.

- Calculate an RBC Ratio Sum for each source area by summing the PCOC-specific RBC ratios for each medium within each source area.

- Apply the CDPHE Conservative Screen decision criteria to each source area.

- Define the AOCs.

The AOCs for OU 3 are defined as one or several source areas grouped spatially and in close proximity. Three surface-soil AOCs and a Great Western Reservoir AOC were identified through the CDPHE Conservative Screen. The AOCs for surface soils are based on sample numbers PT14192, U1A, and U2A (Figure 2-1).

Selection of Chemicals of Concern

The COC selection process was developed by EPA, CDPHE, and DOE as part of the data aggregation process used in the site HHRAs. The COC selection process is used in conjunction with the CDPHE Conservative Screen to aggregate the OU 3 data for the characterization of potential OU 3 risks. The COCs are used in the HHRA to quantify potential risk to exposed receptors in the areas of OU 3 identified by the CDPHE Conservative Screen. The objective of the process is to identify those chemicals in a particular medium that, based on concentration and toxicity, contribute significantly to risks calculated for exposure scenarios involving that medium. The COCs are used in the HHRA to quantify risks associated with exposure to OU 3 media. The COC selection process was based on EPA guidance and agreed upon by EPA, CDPHE, and DOE.

The COC selection process for OU 3 includes application of the following procedures:

- Statistical background comparison tests using, for each analyte in each medium, five different methods (UTL) : (1) hot-measurement test; (2) Gehan test; (3) quantile test; (4) slippage test; and (5) t-test.

- Essential nutrient screen to eliminate those chemicals which, based on documentation in the scientific literature, are considered to be essential for human nutrition.

- Frequency of detection screen; chemicals that were not detected in any samples within a medium and IHSS, and were eliminated as COCs for that medium and IHSS.

- Concentration-toxicity screen to identify those chemicals within each medium and IHSS that were most likely to contribute significantly to risks (99 percent or higher) calculated for exposure scenarios involving the medium and IHSS.

Following the COC selection process, the chemicals remaining were further evaluated using a Preliminary Remediation Goals (PRG) Screen. The maximum detected values for the chemicals whose combined risk factor ratios summed to 0.99 for each medium and IHSS in the concentration-toxicity screen were compared to the corresponding PRGs. Any chemicals with maximum detected values less than the corresponding PRG were eliminated as COCs. Maximum detected values greater than a PRG were retained and evaluated under the weight-of-evidence process.

The weight-of-evidence evaluation involves the application of a variety of data analysis techniques. The results of the evaluation are considered together to assess if levels of chemicals detected in OU 3 represent background conditions or contamination. The following analyses are included in the weight-of-evidence evaluation:

- Comparisons of means, standard deviations, and ranges of OU 3 data to those for data in the Background Geochemical Characterization Report.

- Comparisons of means, standard deviations, and ranges of OU 3 data to benchmark data.

- Probability plot analysis to evaluate data populations.

- Temporal analysis of data to identify seasonal variations or sampling anomalies.

- Spatial analyses combined with the evaluation of physical processes affecting deposition and the evaluation of contribution of various water sources to OU 3 reservoirs.

For those chemicals eliminated as COCs by this step, available data supported the conclusion that detected concentrations of the chemical in OU 3 were representative of background conditions. Americium-241 and plutonium-239, -240 in soil (IHSS 199) and plutonium-239, -240 in surface sediment in Great Western Reservoir (IHSS 200) are the only COCs identified for OU 3.

6.1.3 Exposure Assessment

An exposure assessment is a qualitative and/or quantitative assessment of the type and magnitude of exposures to COCs that are present at or migrating from Rocky Flats. The type of exposure is defined by the available pathways and routes through which receptors may contact COCs. The magnitude of exposure is assessed by estimating the amount of chemical available and the frequency and duration of the contact.

Current Exposure Pathways

The potential receptors and associated exposure pathways have been identified for OU 3 based on the COCs and the AOCs. Based on the land-use restrictions and zoning limitations, the most likely land-use for IHSS 199 and IHSS 200 is recreational, and therefore, this scenario is quantitatively evaluated in the HHRA. In addition, the land-use associated with the most conservative estimates of risk (i.e., residential) is also quantitatively evaluated in the HHRA.

Future Exposure Pathways

Health risks are evaluated for a hypothetical future receptor participating in recreational activities within a 50-acre exposure area in the surface soils AOCs (PT14192, U1A, and U2A). The 50-acre exposure area evaluated in the HHRA includes the three soil-sampling locations identified as AOCs. Therefore, this 50-acre area represents the exposure area presenting the maximum risks to a recreational user of OU 3. The recreational exposure scenario assumes a receptor participates in various recreational activities in the OU 3 area (hiking, biking, picnicking, etc.) and is exposed to plutonium-239, -240 and americium-241 in the surface-soils in the AOCs. Health risks are also evaluated for a hypothetical future resident within a 10-acre exposure area in these AOCs.

Future exposure in IHSS 200 assumes a receptor is exposed to plutonium-239, -240 in sediments in the associated AOCs. The sediments in IHSS 200 include the Great Western Reservoir sediments and the North and South Walnut Creek sediments (from Indiana Street into the reservoir). All plutonium-239, -240 activity data for the samples collected within the 10- or 50-acre exposure areas were used to calculate the exposure-point concentrations.

Health risks are evaluated for Great Western Reservoir using the future use scenario that would provide the greatest risk. This hypothetical exposure scenario is based on the assumption that the reservoir will be drained for residential, recreational, or commercial/industrial uses, thus, exposing the lake-bottom sediments in the center of the reservoir. This scenario was evaluated due to the uncertainty regarding the future use of Great Western Reservoir.

Quantification of Exposure

Exposure is quantified by estimating the intake of media and combining it with the concentration of constituents in the media at the exposure-point. Intake is estimated by combining the parameters that describe the rate of contact with or intake of the media, the frequency of contact, duration of contact and body weight of the exposed individual. Exposure-point concentrations can be estimated by direct measurement at a point of contact or by modeling contaminant release and transport to the point of contact (exposure-point).

Using the exposure-point concentrations of the COCs in IHSS 199 soils and IHSS 200 sediments, it is possible to estimate the potential human intake via each exposure pathway. Chemical intake parameters for the central tendency exposure (CT) (or average exposure) are selected to represent average values for exposure variables. The reasonable maximum exposure (RME) is estimated by selecting values for exposure variables so that the combination of all variables results in the maximum exposure that can reasonably be expected to occur at Rocky Flats.

Internal exposure to radionuclide COCs is assessed in two ways. First, using conventional "dose assessment" methods, the committed effective dose equivalent (CEDE) based on intake of radionuclides via ingestion or inhalation is calculated and compared to radiation protection standards. The CEDE is the summation over specified tissues of the products of the dose equivalent in a tissue or organ and the weighting factor for that tissue over a 50-year period. The second method, using conventional "risk assessment" techniques, involves calculating the intake of each radionuclide and multiplying the intake by an EPA-derived carcinogenic slope factor. This calculation results in an estimation of the risk of cancer associated with ingestion or inhalation of a radionuclide.

Exposure-Point Calculations

The overall objective associated with calculating the exposure-point concentration is to derive a value that represents a conservative estimate of the average concentration contacted at the point of exposure. Typically, this is represented by the 95 percent upper confidence limit (95UCL) on the arithmetic mean concentration. The following describes the process for calculating the exposure-point concentrations for exposure scenarios developed for IHSS 199 and IHSS 200.

<u>IHSS 199 Surface-Soil</u> - Two exposure scenarios for surface soils are quantitatively evaluated in the HHRA: (1) recreational and (2) residential contact. The exposure-point concentrations for all exposure pathways were estimated for these scenarios according to the following:

- For the recreational setting, the 95UCL on the arithmetic mean, assuming a normal distribution, was calculated using all data points located within the 50-acre exposure area.

- For the residential setting, the COC activities associated with each of the sample locations that were identified as a result of the CDPHE Conservative Screen (PT14192; U1A; and U2A) were used to represent individual exposure-point concentrations, each within a 10-acre exposure area.

<u>IHSS 200-Surficial Sediments</u> - Exposure to surficial sediments associated with Great Western Reservoir assumes the reservoir is drained sometime in the future and the area developed for recreational or residential purposes. At that time, it is assumed an individual using the area for recreation or a resident would contact the surficial sediments. The exposure-point concentrations for these scenarios were estimated according to the following:

- For the recreational setting, the 95UCL on the arithmetic mean, assuming a normal distribution, was calculated using all data points located within the 50-acre area.

- For the residential setting, the 95UCL on the arithmetic mean, assuming a normal distribution, was calculated using all data points located within a 10-acre exposure area. The 10-acre exposure area was selected to include those sample locations associated with the highest reported activities of COCs detected in Great Western Reservoir.

Inhalation-specific, exposure-point concentrations were estimated according to the process described above.

6.1.4 Toxicity Assessment

Conducting a toxicity assessment involves assessing the potential for the identified COCs to cause adverse effects in exposed individuals. The toxicity assessment also seeks to develop a reasonable appraisal of the association between the degree of exposure to a contaminant and the possibility of adverse health effects. A chemical agent may not cause adverse effects or toxic effects in biological systems unless the agent, or its metabolic byproducts, reach critical receptor sites in the body at specific levels and for a period of time sufficient to elicit a particular effect. Whether or not a toxic response occurs depends on the chemical and physical properties of the toxic agent, the degree of exposure to the agent, and the susceptibility of an individual to the particular effect. To characterize the toxicity of a particular chemical, the type of effect it can produce and how much is needed to produce that effect must be known.

The toxicity assessment contains two components:

- Hazard identification, which is the process of evaluating the adverse human health effects, if any, that may result from exposure to the COCs.

- Dose-response evaluation, which quantitatively examines the relationship between the level of exposure and the occurrence of adverse health effects in the exposed population. Dose-response relationships, which are expressed as quantitative toxicity reference values for the COCs, are also summed.

Hazard Identification

EPA classifies all radionuclides as human carcinogens, based on their property of emitting ionizing radiation and on the extensive weight-of-evidence provided by epidemiological studies of radiogenic cancers in humans.

The effects of exposure to ionizing radiation fall into three general categories: (1) carcinogenic effects; (2) mutagenic or genetic effects; and 3) teratogenic effects.

<u>Carcinogenic Effects</u> - Ionizing radiation has been demonstrated to induce human cancer. A great deal of data exist correlating high exposures of radiation to cancer induction in humans. In general, scientists agree that the probability of cancer increases with dose, but scientists continue to debate which dose-response model most accurately predicts the effects of low-level radiation exposure. Current radiation-protection standards are based on the idea that each increment of radiation exposure causes a linear increase in the risk of cancer (the linear nonthreshold hypothesis).

<u>Mutagenic (Genetic Effects)</u> - Radiation can cause damage to cells by changing the number, structure, or genetic content of the genes and chromosomes in the cell nucleus. These heritable radiation effects are classified as either gene mutations or chromosome aberrations. Follow-up epidemiological studies of human populations exposed to low doses of radiation have not shown conclusive evidence of heritable effects that are due to radiation exposure. Most scientists agree, however, that these effects may be occurring in numbers so low that they are not detectable in the study populations. Because of the lack of

conclusive human data, animal studies are used to determine risk factors for heritable effects in humans. Current human dose-response models, however, assume that the probability of genetic damage increases linearly with radiation dose, and that there is no evidence of a "threshold" dose for initiating heritable damage to germ cells.

Teratogenic Effects - Relatively high doses of radiation exposure have been shown to produce abnormalities in animals and humans exposed in utero. The effects of radiation exposure to the fetus vary with the stage of gestation. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has developed quantitative risk estimates for effects of prenatal irradiation (primarily mental retardation) over the different stages of pregnancy. Possible risks of fetal radiation exposure include mental retardation, development of fatal cancer after birth, malformation, and preimplantation loss or spontaneous abortion.

Dose-Response Evaluation

In accordance with EPA guidance, the risk associated with radiation exposure is evaluated by using age-averaged slope factors that represent lifetime excess cancer incidence per unit of intake for each radionuclide.

Radionuclide slope factors are calculated for each radionuclide individually, based on its unique chemical, metabolic, and radioactive properties. The slope factors are the average risk per unit intake or exposure for an individual in a stationary population with vital statistics (mortality rates) typical of the United States in 1970. Because of the radiation risk models employed, both the internal and external slope factors are characterized as best estimates (i.e., median or 50th percentile values) of the age-averaged lifetime total excess cancer incidence risk per unit intake or exposure.

The risk of cancer incidence from ingesting or inhaling radioactive contaminants is calculated by multiplying the total lifetime intake by the cancer-incidence risk factor for ingestion or inhalation. These slope factors relate risk of cancer incidence to intake of each radionuclide.

Radionuclides may also elicit deleterious effects on humans without being taken in or brought in contact with the body. External radiation exposures can result from either exposure to radionuclides on site or to radionuclides that have been transported offsite to other locations in the environment. Risk factors for surface-soil contamination were used to calculate increased cancer incidence risks from external exposure. These factors assumed uniform deposition of contaminants over a large area, which leads to an increase in the uncertainty of such calculated risks.

6.1.5 Risk Characterization

This section describes the radiological risk estimation methods and the results of the risk characterization for receptors exposed under recreational and residential settings in IHSS 199 and IHSS 200 based on the assumed exposure conditions. RME and CT risks are estimated for each COC and each exposure pathway. The exposure estimates are compared or combined with toxicity values for the COCs to generate a quantitative risk estimate.

Radiation Dose Estimation Methods—Internal and External Radiation

CEDE for internal radiation exposures and the EDE for external exposure to radiation sources are summed to estimate the total effective dose equivalents (TEDE) which are calculated for all radionuclides and all pathways. For example, the TEDE accounts for radiation exposure resulting from ingestion, inhalation, and external exposures. Total annual radiation dose is equal to the TEDE for 1 year of exposure and can be compared to annual radiation protection standards.

For this assessment, the TEDEs are compared to the DOE annual radiation dose limit for members of the public, including residents and recreationalists. This value is equal to 100 mrem/year for all routes of exposure. TEDEs that exceed 100 mrem/year indicate that the exposure for the radioactive sources exceed regulatory limits.

Cancer Risk Estimation Methods—Intake Based

The potential for carcinogenic effects is evaluated by estimating excess lifetime cancer risk. Excess lifetime cancer risk is the incremental increase in the probability of developing cancer during one's lifetime over the background probability of developing cancer (i.e., if no exposure to site-related COCs occurred). For example, a 2×10^{-6} excess lifetime cancer risk means that for every 1 million people exposed to the carcinogen at the defined exposure conditions averaged over a lifetime, the average incidence of cancer is increased by two occurrences. The NCP suggests a point of departure for remediation goals should be 1×10^{-6}, and EPA guidelines indicate that an excess lifetime cancer risk range of 1×10^{-4} to 1×10^{-6} is required for the protection of human health.

The slope factor gives the incremental risk when applied to the estimated daily chemical intake averaged over a lifetime of exposure. Because of the methods followed in estimating slope factors, the excess lifetime cancer risks should be regarded as upper bounds on the potential cancer risks rather than an accurate representation of true cancer risk.

The intake of a chemical evaluated for carcinogenic health effects (i.e., lifetime average daily intake) is calculated by prorating the total cumulative dose of the chemical over an averaging time of an entire life span. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

The exposure scenarios evaluated for IHSS 199 involve potential exposure to more than one carcinogen. Although synergistic or antagonistic interaction might occur among chemicals at IHSS 199, there is insufficient information in the toxicological literature to predict quantitatively the effect of such interaction. Therefore, consistent with EPA guidelines on chemical mixtures, carcinogenic risks are treated as additive.

Summary of Estimated Risks

IHSS 199—Residential Exposure - The risks associated with residential exposure to plutonium and americium in soil through direct and indirect contact were calculated based on RME and CT conditions. Direct contact exposure is assumed to occur as a result of ingestion and inhalation. Indirect contact is limited to vegetable, beef, and milk consumption and external radiation exposure. The results indicate the following:

- For an adult, and based on a time-weighted soil ingestion rate, the estimated excess lifetime cancer risk is 1×10^{-6} for locations PT14192 and U2A, and 3×10^{-6} for U1A, based on the RME point concentration. For the CT concentration combined with the time-weighted soil ingestion rate, the estimated excess lifetime cancer risk is 1×10^{-7} for PT14192 and U2A, and 2×10^{-7} for U1A.

- For an adult, the TEDE is about 1.2 x 10^{-1} mrem/year, 2.6 x 10^{-2} mrem/year, and 2.3 x 10^{-2} mrem/year for locations PT14192, U1A, and U2A, respectively. The TEDE based on the CT concentration is about 2.5 x 10^{-2} mrem/year, 7.0 x 10^{-3} mrem/year, and 3.9 x 10^{-3} mrem/year for PT14192, U1A, and U2A, respectively. These values are all below the DOE annual dose limit for the general public of 100 mrem/year.

- For a child, the CEDE for ingestion exposures under RME conditions is about 1.4 x 10^{-1} mrem/year for PT14192, 2.3 x 10^{-2} mrem/year for U1A, and 1.3 x 10^{-2} mrem/year for U2A. The corresponding CT values are 3.9 x 10^{-2} mrem/year, 6.4 x 10^{-3} mrem/year, and 3.6 x 10^{-3} mrem/year for PT14192, U1A, and U2A, respectively.

IHSS 199—Recreational Exposure - The risks associated with exposure to soil under recreational use of a 50-acre plot in IHSS 199 (includes the individual 10-acre plots where the presence of COCs were identified) were calculated based on RME and CT parameters. Exposure is assumed to be limited to soil ingestion, inhalation, and external radiation exposure. The results indicate the following:

- For an adult, the RME concentration of plutonium and americium resuldt in an estimated excess lifetime cancer risk of 5 x 10^{-8}. The corresponding CT risk is estimated at 3 x10^{-9}.

- For an adult, the RME TEDE is estimated at 3 x 10^{-3} mrem/year; the corresponding CT TEDE is estimated at 5.7 x 10^{-4} mrem/year. Both estimates are below the DOE annual dose limit for the general public of 100 mrem/year.

- For a child, the RME CEDE for soil ingestion is estimated at 5.2 x 10^{-3} mrem/year. The corresponding CT CEDE is estimated at 1 x 10^{-3} mrem/year. Both estimates are below the DOE annual dose limit for the general public of 100 mrem/year.

IHSS 200—Residential Exposure - Exposure to sediments located in IHSS 200 assumes that Great Western Reservoir is drained and subsequent residential or recreational development occurs in the reservoir basin.

The risks associated with exposure to sediment, based on residential and recreational exposure conditions, were calculated using RME and CT parameters. Exposure is assumed to include: ingestion, inhalation, external radiation exposure, and fruit, vegetable, beef, and milk consumption. The results indicate the following:

- The RME estimated excess lifetime cancer risk resulting from exposure associated with the above pathways could be as much as 9 x 10^{-7}; this includes risk from all pathways except internal and external radiation. The corresponding CT estimated excess lifetime cancer risk is 6 x 10^{-8}. These risks are based on adult exposure and associated intake assumptions.

- For an adult, the RME TEDE is estimated at 6.5 x 10^{-3} mrem/year; the corresponding CT TEDE is estimated at 1.5 x 10^{-3} mrem/year. These values include exposure to internal and external radiation sources and are below the DOE annual dose limit for the general public of 100 mrem/year.

- For a child, the RME CEDE for sediment ingestion is estimated at 8 x 10^{-3} mrem/year. The corresponding CT CEDE is estimated at 2.2 x 10^{-3} mrem/year. Both estimates are below the DOE annual dose limit for the general public of 100 mrem/year.

IHSS 200—Recreational Exposures - Exposure to Great Western Reservoir sediments is assumed to occur in the future if the reservoir is drained and subsequent recreational use of the area occurs. Under recreational conditions, exposure is assumed to occur to sediments by ingestion, inhalation, and external radiation exposure.

- The estimated excess lifetime cancer risk, based on adult exposure, is estimated to be 1 x 10^{-8} assuming RME exposure conditions. The corresponding estimated excess lifetime cancer risk for the CT exposure setting is 8 x 10^{-10}.

- The RME TEDE is estimated at about 1.4 x 10^{-4} mrem/year for an adult exposed to Great Western Reservoir sediment. The estimated CT TEDE is 1.4 x 10^{-5} mrem/year. These values include exposure to internal and external sources of radiation and are below the DOE annual dose limit for the general public of 100 mrem/year.

- For a child, the RME CEDE for sediment ingestion is estimated at 1 x 10^{-4} mrem/year. The corresponding CT CEDE is estimated at 2 x 10^{-5} mrem/year. Both estimates are below the DOE annual dose limit for the general public of 100 mrem/year.

Dermal Exposures

The BRA recognizes the potential for receptors to experience dermal contact with surface-soils located in IHSS 199 and surficial sediments associated with IHSS 200. The BRA quantified the potential risk associated with external radiation exposure; however, appropriate dose-response and dermal adsorption data have not been collected with which to quantitatively describe the impact of dermal exposure to plutonium or americium.

Comparison of COC-related Risk to Risk from Background

Even though none of the TEDE estimates exceeded the DOE annual radiation dose limit for the general public, it is important to understand the contribution of radiation dose from background conditions as a point of comparison. The TEDE values estimated in this risk characterization represent the amount of radiation received over and above the contribution from background sources of radiation. The background sources of radiation that the general public are exposed to include cosmic radiation from the sun or medical x-rays.

The U.S. average background radiation is about 300 mrem/year, including exposure to radon. Radiation received from routine medical treatment averages about 50 mrem/year in the United States. More specifically, background levels of radiation in the Denver area are estimated to be as high as 350 to 700 mrem/year. These levels are higher than the national average because of the high natural levels of radium, thorium, and radon and because solar radiation exposure increases with increased altitude.

The BRA assumes that, sometime in the future, Great Western Reservoir is drained, and subsequently developed for residential land-use. Under these circumstances, residential receptors could be exposed to the IHSS COCs, in addition to those constituents present at background levels. Comparing the estimated excess lifetime cancer risk as a result of exposure to arsenic and beryllium, which were detected in IHSS 200 at background-level concentrations, to the risk associated with exposure to plutonium under the same exposure conditions, shows that the risks due to background exceed those attributable to Rocky Flats-related contamination. The estimated excess lifetime cancer risk for arsenic, based on the maximum detected concentration in sediments, could be as much as 6 x 10^{-5}. For beryllium, the comparable value is about 4 x 10^{-5}. The highest anticipated risk due to exposure to plutonium in IHSS 200 surface sediments could be as much as 9 x 10^{-7}, or about two orders of magnitude lower than that for background arsenic and beryllium. Consequently, populations that contact the soil or sediments associated with these areas are not expected to experience an excess lifetime cancer risk that exceeds contribution expected from background sources. Quantitatively, this can be expressed as follows:

- Background risk from arsenic and beryllium combined is about 1 x 10^{-4} (0.0001) or about 1 in 10,000.

- The maximum risk estimated based on exposure to plutonium and americium detected in IHSS 199 U1A totals about 3 x 10^{-6} (0.000003), or about 3 in 1,000,000.

6.1.6 Uncertainty Analysis

The uncertainty analysis is a synopsis of the human health risk assessment in Appendix A. Therefore, a more in-depth and site-specific uncertainty analysis is found in Appendix A.

Uncertainties in the baseline risk assessment are assessed qualitatively instead of quantitatively. A qualitative analysis is appropriate given that the Reasonable Maximum Exposure (RME) risks are well within the EPA's acceptable risk range of 1 x 10^{-4} to 1 x 10^{-6}. Because RME risks represent upper bound risks, a quantitative uncertainty analysis would better define the distribution of risks below the RME level. Therefore, because all risks within this distribution will be acceptable, a quantitative uncertainty analysis is not warranted.

Uncertainties are associated with each step in the BRA process. Uncertainties specific to the evaluation of OU 3 are addressed in this section.

- Environmental sampling may not have accurately characterized chemical concentrations or radionuclide activities. Two sampling methodologies were used to collect soil samples in OU 3 for radionuclide analysis. Use of the data sets in the assessment assumes the data collection methods are comparable. This assumption could over or under estimate risk.

- One major area of uncertainty in the exposure assessment is the prediction of human activities that may lead to contact with COCs in environmental media. The degree to which exposure models fully reflect the activities and processes that may lead to contact with constituents in environmental media cannot be estimated. This uncertainty could over or under estimate risk.

- Specific land-use assumptions that may lead to an overestimate of exposure, and subsequently risk, include:

  - Future development of the area currently occupied by Great Western Reservoir (IHSS 200) for residential or recreational uses and subsequent exposure to sediments currently 40 feet beneath the reservoir surface.

- Future residential development of the Remedy Lands.

- Future reliance on homegrown vegetables, beef, or dairy products cultivated or raised on land within IHSS 199 or land currently inundated by Great Western Reservoir (IHSS 200).

- No contaminant loss due to leaching, erosion, or runoff was considered. This could lead to an overestimate of risk, because these processes would lead to a reduction in the concentration of a contaminant over time.

- The risk of increased incidence of cancer or of fatal cancer from exposure to low-level radiation is determined by applying a risk factor to either the radiation dose or the radionuclide intake. Regardless of the type of risk factor used, the same basic uncertainties remain. The uncertainties are related to the model used for determining the health effects of radiation exposure, which are based on the average risk per unit intake for an individual. This uncertainty could over or under estimate risk.

- For exposure to ionizing radiation, data to establish dose-response estimates are taken primarily from studies of human populations exposed to high levels of radiation. These include atomic bomb survivors, underground miners, radium dial painters, patients injected with thorotrast or radium, and patients who received high x-ray doses during various treatment programs. The major source of uncertainty in determining low-level radiation risks is extrapolation of these data to much lower doses. This uncertainty could over or under estimate risk.

6.2 ECOLOGICAL RISK ASSESSMENT

This summary presents the results of the ERA. The complete ERA is presented in Appendix B. A terrestrial evaluation was conducted for IHSS 199, where as an aquatic evaluation was conducted for IHSS 200, IHSS 201, and IHSS 202.

The ERA presents the methods and results of the Preliminary Problem Formulation as a phase defined by the EPA in 1994. The purpose of the Preliminary Problem Formulation is to assess the potential ecological effects (terrestrial and aquatic, where appropriate) associated with Rocky Flats using a conservative 'worst-case' approach, in order to determine if further investigation or remedial action is necessary. The current and future risks associated with Rocky Flats under the no action alternative are assessed based on the data collected.

Specific data collection activities were designed and implemented to meet the needs of the ERA evaluation and phased approach. These particular methods and their rationale are provided within the OU 3 Work Plan (DOE, 1992a).

6.2.1 ERA Approach

The ERA follows several EPA guidance documents including:

- Ecological Risk Assessment Guidance for Superfund (EPA, 1994b).

- Framework for Ecological Risk Assessment (EPA, 1992b).

- Risk Assessment Guidance for Superfund, Volume II Environmental Evaluation (EPA, 1989b).

- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference Document (EPA, 1989c).

In addition, various components of the ERA have been documented as part of a sitewide assessment of ecological risk in two Technical Memoranda (TMs) produced by DOE:

- Sitewide Conceptual Model (TM2) (DOE, 1995c)

- Ecological Contaminant of Concern Selection Techniques (TM3) (DOE, 1995d)

The EPA guidance identifies an eight step process for the completion of an ERA. The initial phase of this process is termed a Preliminary Problem Formulation and serves to identify preliminary risks based upon a conservative 'worst-case' analysis approach. If a risk is identified, it is further evaluated within the remaining steps of the ERA process by further sampling, evaluation, etc. If no risk is identified (as was the case for OU 3), the process is terminated upon completion of the Preliminary Problem Formulation.

The ERA presents the methods and results of the Preliminary Problem Formulation which include:

- Preliminary exposure assessment.

- Preliminary effects assessment.

- Preliminary risk characterization.

PCOCs were identified for soils using statistical tests (derived from the 0 to 3 cm fraction of 11 trench and 2 soil plots collocated with terrestrial plant and small mammal sampling efforts), and surface water and surface sediment (derived from all data collection activities for OU 3 for total surface water and grab sediment samples). PCOCs were identified as those chemicals with concentrations or activities above those of background. A weight-of-evidence evaluation was conducted for the surface water and sediment (as described within the CDPHE Conservative Screen Letter Report [DOE, 1994e]).

Results of the screen identified plutonium-239, -240 as a PCOC for sediment within IHSS 200, and plutonium-239, -240 and americium-241 as PCOCs for IHSS 199 (soils). As a conservative measure, both plutonium-239, -240 and americium-241 were retained as aquatic PCOCs in sediment for each IHSS.

The ERA comprises the preliminary assessment of exposure and effects, which provides the final step in the PCOC screen for OU 3. The observed exposure-point concentrations and determined dose are developed within the exposure assessment. The effects assessment compares these two values to literature benchmark values for the no observable adverse effects level (NOAEL) to determine if an exceedance occurs. Results of in-field biometric measurements of effects (species diversity and bioassay analysis of surface water and sediment toxicity) are also presented within the effects assessment to provide a weight-of-evidence analysis. Upon completion of the estimation of concentrations exposure-point activity, exposure dose comparison to NOAEL levels, and interpretation of the biometric measures, the final PCOC screening step is completed. The results are then summarized, along with the uncertainty involved with the analysis, within the risk characterization.

6.2.2 Ecological Setting

A comprehensive description of the ecological setting of Rocky Flats setting is provided in TM2, Sitewide Conceptual Model (DOE, 1995c). The biotic (living) components of the OU 3 ecological setting exist in a variety of terrestrial and aquatic environments. The terrestrial ecology encompasses dry upland prairie type ecosystems to cottonwood riparian/wetland areas. The predominant habitats are dry upland short-grass areas. Many of these areas have historically been impacted by grazing and agriculture.

The aquatic areas include lakes and streams. All of the aquatic areas are managed for water use, therefore flows change seasonally and are dependent upon precipitation and use. The streams are ephemeral in nature, therefore existing populations are opportunistic. Mower Reservoir and Standley Lake contain a diversity of fish due to stocking practices, whereas Great Western Reservoir is characterized strictly by opportunistic species.

6.2.3 OU 3 Data

The database for this ERA includes information acquired from the following sources:

- OU 3-specific field investigations from May to June 1993

- Data for abiotic and biotic samples collected by DOE as part of the ongoing Rocky Flats environmental monitoring programs

Particular data needs for the ERA were identified early within the project. Sampling efforts were designed to meet the specific objectives of the assessment. Collocated (in time and space) samples of soil, vegetation, and small mammals were gathered from 11 trench and 2 soil plot locations. These locations were established based upon a gradient approach, to observe any potential trends in PCOC occurrence and uptake within the terrestrial ecosystem.

Similarly, aquatic media of surface water, sediment (grab 0 to 12 inches), benthic macroinvertebrates (analyzed for species occurrence), and fish tissue (analyzed for target metals and radionuclides), were collocated to determine PCOC occurrence and uptake within the aquatic ecosystem. However, because conclusions could not be drawn regarding PCOC uptake and transfer between these media based upon the results (there were minimal detections in tissues), a conservative approach of utilizing all available data for each medium was conducted. Therefore, surface water results were combined (by IHSS) and available grab sediment data were also combined (by IHSS) from available data sources for OU 3.

Biotic media of vegetation, small mammals, and fish were collected for PCOC content analysis. Results of these analysis were used within the effects assessment to determine exposure dose.

Biotic samples of benthic macroinvertebrates and periphyton were also collected for the determination of species occurrence. Species occurrence can provide an indication of ongoing environmental health, and was, therefore, used qualitatively within the effects assessment to determine if PCOC effects are ongoing. The results of these measures were strictly qualitative because other factors such as water quality conditions of pH, temperature, light penetration, and depth are also driving factors for species occurrence.

Bioassay analysis of surface water and sediment was also conducted at certain areas within OU 3. The toxicity of these media to standard test organisms (ceriodaphnia and fathead minnows) was conducted. Results were qualitatively interpreted and provided within the effects assessment.

6.2.4 Identification of Potential Chemicals of Concern

PCOCs were identified as those chemicals that occur at levels above those of background. A weight-of-evidence comparison was conducted for surface water and sediment and is described in detail within the CDPHE Conservative Screen Letter Report (DOE, 1994e). Soils were evaluated statistically. The same methodology for PCOC selection used in the CDPHE Conservative Screen Letter Report (DOE, 1994e) was used to select PCOCs for the ERA. However, for the ERA, subsurface sediments and groundwater were not considered exposure pathways for ecological receptors so those media were not evaluated further.

Results of the PCOC screen for the ERA identified plutonium-239, -240 and americium-241 as a PCOC in soils (IHSS 199) and plutonium-239,-240 as a PCOC in sediment within IHSS 200. As a conservative measure, both plutonium-239, -240 and americium-241 were retained as sediment PCOCs for IHSS 200, IHSS 201, and IHSS 202. There were no surface-water PCOCs identified as a result of the background weight-of-evidence screen.

6.2.5 Exposure Assessment

Exposure to terrestrial and aquatic receptors was conducted by different techniques. The following provides a discussion of the methods and results of the exposure assessment. The exposure assessment identifies exposure pathways, receptors of concern, and the exposure-point concentration and activity (and dose). The results of the exposure assessment included the identification of PCOC exposure-point concentration and activity and PCOC exposure dose (measured in tissue for the terrestrial assessment versus modeled for the aquatic assessment).

Terrestrial

The OU 3 terrestrial ecosystem is characterized by the presence of various "physical stressors" that have exhibited effects to the ecosystem structure. Various land-use practices such as grazing, agriculture, and industry have shaped the habitat and its usability by wildlife.

Because of the chemical and physical nature of the PCOCs, soil was considered the primary source of exposure medium. Transuranic radionuclides are not highly mobile within the environment and soil would provide the most significant exposure pathway to resident organisms of plants and small mammals. Due to their transient nature, larger foraging organisms such as deer, are much less likely to become exposed.

Taking into account the ecological characteristics of Rocky Flats, in addition to the physical and chemical characteristics of the PCOCs, the principal receptors of concern are plants and small mammals. Therefore, the terrestrial sampling activities (and subsequent risk assessment) focus upon these organisms.

Exposure was measured in OU 3 using a gradient, collocated sampling design. Samples of collocated soil, vegetation, and small mammals were gathered from areas close to Rocky Flats and progressing further away (potentially less contamination). The resulting activities of plutonium and americium in plant and animal tissues were typically less than the minimum detectable activity (MDA); some were reported as negative values. Uptake and transfer of the COCs, therefore, appeared to be minimal.

Aquatic

The OU 3 aquatic ecosystems encompass Great Western Reservoir, Standley Lake, Mower Reservoir, and reaches of Woman, Walnut, and Big Dry Creek. Resident populations are dependent upon reservoir use. For instance, Great Western Reservoir is a potable water retention reservoir, and is not managed for fish species diversity. Therefore, the species composition includes opportunistic species of carp, sucker, and minnow; whereas Mower Reservoir and Standley Lake are managed for recreational purposes and, therefore, contain a diversity of game fish species (thereby affecting exposure duration due to the stocking practices).

Results of the PCOC evaluation identified plutonium-239, -240 for sediments in IHSS 200. As a conservative measure, plutonium-239, -240 and americium-241 were evaluated for each IHSS. Each IHSS is geographically isolated from one another, therefore independent assessments of aquatic risk were conducted.

The principal receptors of concern were identified as those that are exposed to sediment and would include bottom-dwelling fish, benthic macroinvertebrates, and fish eggs. Exposure-point concentration/activity were conservatively assumed to be the maximum observed activity for each PCOC, within each IHSS. An internal exposure dose (external for the fish eggs) was modeled for each receptor using techniques described by Blaylock et al., 1993. The maximum observed exposure-point concentration/activity was used as the basis of the exposure dose calculation.

6.2.6 Effects Assessment

An effects assessment serves to identify possible effects to the exposed receptors (as identified within the exposure assessment) by comparing the determined exposure-point concentration/activity and exposure dose to literature derived NOAEL benchmark levels. If an exceedance occurs, an effect can be inferred.

Supplemental effects measurements, such as the species diversity and bioassay analysis of surface water and sediment, also identify potential effects, possibly missed with the conservative benchmark screen.

Terrestrial

Effects for the terrestrial assessment were measured by an evaluation of PCOC occurrence and uptake within the OU 3 ecosystem. Results of the evaluation indicated no effect. Biometric measurements (plant cover and diversity) were not relied upon because conflicting effects due to land-use practices (grazing) were identified.

The measured activities levels of plutonium-239, -240 and americium-241 from the 11 trench and 2 soil plot locations were 1.593 and 0.272 pCi/g respectively. Most of the animal tissues had activities below the MDA, including negative values. The maximum activity for americium-241 in an animal was 0.16 pCi/g. The activity ratio of americium in animal and plant tissue to soil was 0.027. The dose for the highest tissue activity measured for animals of 0.16 pCi/g gives 0.84 mrad/d dose. The dose to animal tissue from plutonium at 0.026 pCi/g was calculated to 0.14 mrad/d. These values are both below the 100 mrad/d dose considered protective of animal and vegetative tissue.

Aquatic

The maximum observed exposure-point concentration/activity level for each PCOC was evaluated by IHSS. These activity levels were compared to literature-derived NOAELs of 5×10^{-5} pCi/g and 5×10^{-4} pCi/g for plutonium and americium, respectively. Results were also quantified using the hazard quotient and hazard index (sum of hazard quotients by receptor). In general, hazard quotients of 1 or greater indicate a potential risk.

Results of the activity comparison resulted in hazard quotients of:

- IHSS 200: plutonium-239, -240 and americium-241 of 8.1×10^{-6} and 2.03×10^{-5}, respectively
- IHSS 201: plutonium-239, -240 and americium-241 of 1.1×10^{-6} and 2.1×10^{-6}, respectively
- IHSS 202: plutonium-239, -240 and americium-241 of 9.7×10^{-7} and 2.0×10^{-5}, respectively

These values fall below a hazard quotient of 1 by at least 5 orders or magnitude.

Comparison of the calculated exposure dose was also compared to a literature-derived NOAEL dose of 0.4 mGy/h. Results were evaluated using the hazard quotient and hazard index technique. Hazard quotients for each IHSS were:

- IHSS 200: plutonium-239, -240 and americium-241 of 0.05 and 0.006, respectively
- IHSS 201: plutonium-239, -240 and americium-241 of 0.003 and 0.0007, respectively
- IHSS 202: plutonium-239, -240 and americium-241 of 0.003 and 0.0006, respectively

All hazard quotients are below a level of 1 indicating no effect.

Results of the diversity evaluation for benthic macroinvertebrate species indicated that the species present are representative of typical species for the area. The bioassay analysis also indicated no apparent effect to laboratory organisms exposed to surface water and sediment.

6.2.7 Risk Characterization

Several approaches were compiled to provide a weight-of-evidence evaluation of effects and risk to ecological receptors exposed to the PCOCs. Results of the hazard quotient and hazard index evaluation revealed levels below 1 for all receptors. Similarly, in-field measurements also indicated no risk to the resident populations.

The Preliminary Problem Formulation was based upon conservative assumptions including the following:

- The observed maximum activity of each PCOC is the exposure-point concentration/activity

- The observed activity of each PCOC is 100 percent bioavailable

Measured tissue concentrations that are correlated in space and time to soil PCOC content reduced the uncertainty for the terrestrial evaluation. The results of the terrestrial assessment are site-specific and indicate no effect.

The aquatic assessment could not rely upon the collocated information as heavily as the terrestrial assessment, due to the transient nature of the receptors (fish were stocked) and the influence of other variables. Therefore, the aquatic assessment encompasses conservative assumptions which lead to higher uncertainty. However, using the weight-of-evidence effects and risk characterization evaluation, there appear to be no effects to the aquatic receptors of OU 3 attributable to PCOC occurrence.

7.0 SUMMARY OF RFI/RI REPORT

The results of the RFI/RI confirm the results of historical investigations regarding the distribution of contaminants in the Offsite Areas that surround Rocky Flats. Because the OU 3 RFI/RI was able to use an extensive data set, the nature and extent determination is much refined over earlier investigations. While the area east of the Rocky Flats east gate has elevated levels of plutonium-239, -240 and americium-241 relative to regional global fallout levels, evaluations of nature and extent of contamination, fate and transport of contamination, human health risk assessment (HHRA), and ecological risk assessment (ERA) indicated that OU 3 does not appear to have contaminant levels sufficient to pose significant risk to human health or the environment.

7.1 NATURE AND EXTENT OF CONTAMINATION SUMMARY

7.1.1 Soils

Based on a background comparison and the COC selection process, plutonium-239, -240 and americium-241 are elevated above background levels but are only elevated above risk-based screening levels (benchmarks) in three 10-acre soil plots (PT14192, U1A, and U2A). These analytes are considered to be COCs at these locations. The highest levels of plutonium-239, -240 and americium-241 are located east of Indiana Street in the area of the Remedy Lands. Uranium isotopes are neither considered to be above background levels nor are they considered to be COCs.

In the subsurface soil samples, the highest levels of plutonium-239, -240 and americium-241 were detected from 0 to 6 cm. Below 10 cm, activities of americium and plutonium are within background ranges. Patterns of activities for these two analytes in the trench profiles suggest wind-blown contamination from Rocky Flats as the source for americium-241 and plutonium-239, -240 in OU 3 soils.

7.1.2 Surface Water

Based on background and benchmark comparisons, no surface-water analytes in OU 3 are considered to be significantly elevated over naturally occurring levels. No COCs were identified for surface water in any of the reservoirs. These findings are consistent with the historical sampling that has been performed in the reservoirs by the surrounding Cities of Broomfield, Thornton, Northglenn, and Westminster.

7.1.3 Sediment

In Great Western Reservoir, all radionuclides except plutonium-239, -240 were found at background levels in the sediments. In addition, metals were found to be present in sediments within naturally occurring background levels, except copper, which was elevated above background levels in subsurface sediments. Copper was eliminated by the COC selection process based on the concentration-toxicity screen. The COC selection process identified plutonium-239, -240 as the one COC for sediments in Great Western Reservoir.

In general, activities of radionuclides in Standley Lake sediments were found at or near background levels. Concentrations of some metals in the subsurface core samples (i.e., arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, potassium, silver, and zinc) were elevated over stream sediment background levels in Standley Lake. However, spatial analysis and information regarding the sources of water feeding Standley Lake indicate that these metals are not associated with releases from Rocky Flats. Most of the water flowing into Standley Lake originates from Clear Creek. These analytes were eliminated as PCOCs based on spatial analysis. No analytes were determined to be COCs in the sediments of Standley Lake.

All radionuclides and other metals were found at background levels in Mower Reservoir except calcium in surface sediments and potassium in subsurface sediments. Calcium and potassium were eliminated as COCs because they are essential human nutrients. No analytes were determined to be COCs for the sediments of Mower Reservoir. The source of water to Mower Reservoir originates entirely from Rocky Flats, and of the three reservoirs, may be the most representative of influences from Rocky Flats.

7.1.4 Groundwater

The groundwater wells installed for OU 3 indicate that contaminants are not migrating from the reservoirs to the groundwater system within OU 3. Based on a qualitative comparison to background groundwater data, potassium and strontium are the only constituents with concentrations that exceed background levels in Well 49192. No constituents exceed background levels in Well 49292. No COCs were identified for OU 3 groundwater. In addition, the groundwater pathway is not a complete pathway from a human health exposure standpoint.

7.1.5 Air

As part of the OU 3 air sampling program, three ultra high-volume (approximately 500 cubic feet per minute) air monitoring stations were installed in the vicinity of Standley Lake to characterize the potential for dispersion of plutonium-contaminated soils and sediments. The air sample filters from all three monitoring stations will be analyzed for concentrations of plutonium, americium, and uranium. No data are available for the three air monitoring stations at this writing. It is anticipated that approximately 6 months of air monitoring data will be presented in the final version of the RFI/RI report for use in the OU 3 risk assessment.

Portable wind tunnel tests were conducted to quantify wind resuspension emissions of particulate matter from the soils and sediments of OU 3. The highest threshold velocities were found on the vegetated terrestrial areas without any surface disturbance (velocities greater than 80 mph at the 10-m reference height) while the lowest threshold velocities were found at the shoreline areas that were extensively disturbed by artificial means. Information from the wind tunnel study was used in evaluating the inhalation pathway for the HHRA.

7.2 FATE AND TRANSPORT

Based on the fate and transport evaluation, the most significant transport pathway for OU 3 has been identified as the direct airborne movement (resuspension) of contaminated soil (current and future exposure) and exposed surficial reservoir sediments (future exposure, if Great Western Reservoir is drained).

Plutonium has been detected above background in OU 3 soils and sediments. The mobility of plutonium tends to have the following characteristics:

- Resuspension and dispersion via wind and water while attached to a solid phase
- Low availability in soil attributed to rapid adsorption to clay, metal oxides, and organic matter

- Very limited downward movement in the soil column via mass flow, diffusion, or mass transport
- Insignificant dissolution of plutonium in natural waters
- Insignificant transport via biological activity
- Physical transport mechanisms are more significant than chemical processes

The box model and FDM results indicate that plutonium levels in resuspended particulates are very low (approximately 6 x 10^{-6} pCi/m^3). The modeled results from both the box model and the FDM are consistent with data from the perimeter RAAMP samplers used to measure levels of plutonium in ambient air at the site perimeter.

7.3 HUMAN HEALTH RISK ASSESSMENT

The purpose of the HHRA is to assess the potential human health risk associated with the Site and to provide a basis for determining whether or not remedial actions are necessary. Results of the data evaluation activities conducted as part of the HHRA indicate that most of the analytes detected within OU 3 are found at concentrations/activities within background levels. The COCs that were identified and evaluated in the HHRA are the following:

- Plutonium-239, -240 was found elevated above background levels and risk-based screening levels in soil plots in the Remedy Lands and in sediments in Great Western Reservoir.
- Americium-241 was found to be elevated above background levels and risk-base screening levels in soil plots in the Remedy Lands.

Residential- and recreational-based exposure scenarios were evaluated for COCs and source areas that were carried through the HHRA. Tables 7-1 through 7-5 present the summaries of the total risks, both for the total effective dose equivalents (TEDE) and cancer risk estimates. Both the reasonable maximum exposure (RME) and central tendency exposure (CTE) are presented.

The OU 3 TEDE were compared to the DOE annual radiation dose limit for members of the public, including residents and recreationalists. This value is equal to 100 mrem/year for all routes of exposure. TEDEs that exceed 100 mrem/year indicate that the exposure for the radioactive source do not exceed regulatory limits. The highest TEDE for OU 3 was 0.12 mrem/year at location PT14192 (see Table 7-1). This is three orders of magnitude less than the 100 mrem/year annual dose limit for the general public.

The potential for carcinogenic effects is evaluated by estimating excess lifetime cancer risk. Excess lifetime cancer risk is the incremental increase in the probability of developing cancer during one's lifetime over the background probability of developing cancer (i.e., if no exposure to site-related COCs occurred). The NCP indicates that a point of departure for remediation goals should be 1 x10^{-6}. EPA guidlelines indicated that a risk range of 1 x10^{-4} to 1 x10^{-6} is protective of human health.

The highest cancer risks based on the conservative residential RME to plutonium-239, -240 and americium-241 is due to soils at location U1A. The estimated cancer risk for this soil plot is 3 x10^{-6}. The residential exposure risks range from 1 x10^{-6} to 6 x 10^{-8} for the other soil source areas and sediments

Table 7-1
Risk Summary for IHSS 199

	RME Residential Adult					
	Cancer Risk			CEDE/EDE		
Pathway	PT14192	U1A	U2A	PT14192	U1A	U2A
Soil ingestion	1E-06	3E-06	1E-06	0.072	0.012	0.007
Soil inhalation	2E-08	3E-08	2E-08	0.0086	0.013	0.0071
Soil external	6E-08	2E-09	1E-09	0.018	0.001	0.008
Vegetable consumption	7E-08	7E-08	4E-08	1.6E-2	3.7E-4	2.1E-4
Beef consumption	1E-08	2E-10	9E-11	3.7E-3	9E-7	7.4E-3
Milk consumption	1E-11	2E-11	1E-11	5.6E-6	2.3E-7	1.3E-7
Total	1E-06	3E-06	1E-06	1.2E-1	2.6E-2	2.3E-2

Notes:

RME = Reasonable maximum exposure.
CEDE = Committed effective dose equivalent (mrem/yr).
EDE = Effective dose equivalent-1 year exposure-external exposure only mrem/yr.

Table 7-2
Risk Summary for IHSS 199

	CT Residential Adult					
	Cancer Risk			CEDE/EDE		
Pathway	PT14192	U1A	U2A	PT14192	U1A	U2A
Soil ingestion	1E-07	2E-07	1E-07	0.015	0.0025	0.0014
Soil inhalation	2E-09	3E-09	2E-09	0.0027	0.0047	0.0023
Soil external	5E-09	2E-10	9E-11	0.0036	0.0003	0.0002
Vegetable consumption	3E-09	3E-09	2E-09	0.002	5E-5	3E-5
Beef consumption	1E-09	2E-11	1E-11	1.5E-3	2.6E-7	2E-7
Milk consumption	1E-12	1E-12	8E-13	2.3E-6	9.6E-8	5.3E-8
Total	1E-07	2E-07	1E-07	2.5E-2	7E-3	3.9E-3

Notes:

CT = Central tendency exposure.
CEDE = Committed effective dose equivalent (mrem/yr).
EDE = Effective dose equivalent-1 year exposure-external exposure only mrem/yr.

Table 7-3
Risk Summary for IHSS 199

	Adult			
	RME Recreational		CT Recreational	
Pathway	Cancer Risk	CEDE/EDE	Cancer Risk	CEDE/EDE
Soil ingestion	5E-08	0.0026	3E-09	0.00052
Soil inhalation	1E-09	0.00052	3E-11	0.000043
Soil external	1E-09	6.6E-5	5E-11	3.25E-6
Total	5E-08	3E-3	3E-9	5.7E-4

Notes:

RME = Reasonable maximum exposure.
CT = Central tendency exposure.
CEDE = Committed effective dose equivalent (mrem/yr).
EDE = Effective dose equivalent-1 year exposure-external exposure only mrem/yr.

Table 7-4
Risk Summary for IHSS 200

	Adult			
	RME Recreational		CT Recreational	
Pathway	Cancer Risk	CEDE	Cancer Risk	CEDE
Soil ingestion	9E-07	4E-03	6E-08	8E-04
Soil inhalation	5E-09	1.9E-03	5E-10	6.1E-04
Soil external	7E-10	4.8E-04	6E-11	9E-05
Vegetable consumption	2E-08	1.3E-04	9E-10	2E-05
Beef consumption	2E-11	1.3E-07	2E-12	3.3E-08
Milk consumption	6E-12	3.3E-08	5E-13	8.5E-09
Total	9E-07	6.5E-03	6E-08	1.5E-03

Notes:

RME = Reasonable maximum exposure.
CT = Central tendency exposure.
CEDE = Committed effective dose equivalent (mrem/yr).
EDE = Effective dose equivalent-1 year exposure-external exposure only mrem/yr.

Table 7-5
Risk Summary for IHSS 200

	Recreational			
	RME		CTE	
	Adult			
Pathway	Cancer Risk	CEDE	Cancer Risk	CEDE
Sediment ingestion	1E-08	1E-04	8E-10	1E-05
Sediment inhalation	1E-10	4.3E-5	3E-12	3.6E-06
Sediment external	4E-12	7E-07	2E-13	3.4E-08
Total	1E-08	1.4E-04	8E-10	1.4E-05

Notes:

RME = Reasonable maximum exposure.
CTE = Central tendency exposure.
CEDE = Committed effective dose equivalent (mrem/yr).

in Great Western Reservoir. These residential risks are well within or below the levels of concern (1×10^{-4} to 1×10^{-6}) to be protective of human health.

The cancer risks based on a recreational exposure to either the surficial soils or the sediments of Great Western Reservoir range from 5×10^{-8} to 8×10^{-10}. These cancer risks are well below the point of departure for remediation goals as stated in the NCP and well below the levels of concern for human health.

7.4 ECOLOGICAL RISK ASSESSMENT

An ecological risk assessment (ERA) was conducted for OU 3 to evaluate the potential contaminant effects to the terrestrial and aquatic ecology. The PCOCs evaluated in the ERA include:

- Plutonium-239, -240 in sediments in Great Western Reservoir, Standley Lake and Mower Reservoir.

- Plutonium-239, -240 and americium-241 in soils from the Remedy Lands.

Results of the ERA assessment indicate minimal risk to either the terrestrial or aquatic ecology as a result of the occurrence of the PCOCs present in the soil and sediment. Observed activities of plutonium-239, -240 and americium-241 and determined doses are well below benchmark levels, which represent levels where no adverse effects are observed. Hazard quotients for plutonium-239, -240 and americium-241 in sediments were 8.1×10^{-6} and 2.0×10^{-5} for Great Western Reservoir, 1.1×10^{-6} and 2.1×10^{-6} in Standley Lake, and 9.8×10^{-7} and 1.9×10^{-6} for Mower Reservoir, respectively. Dose comparison hazard quotients of 0.05 and 0.007 for plutonium-239, -240 and americium-241, respectively, were determined for benthic macroinvertebrates, fish, and fish eggs in Great Western Reservoir, 0.003 and 0.0007 for Standley Lake and 0.003 and 0.0006 for Mower Reservoir.

Hazard Indices were also calculated (combining the hazard quotients for each PCOC). The dose hazard index for benthic macroinvertebrates, fish and fish eggs was 0.11 for Great Western Reservoir, 0.008 for Standley Lake, and 0.007 for Mower Reservoir. A hazard index of 1 or greater typically triggers concern. The Hazard Indices are at least one order of magnitude less than levels that might indicate a potential problem to the terrestrial or aquatic environment.

7.5 CONCLUSION

The OU 3 RFI/RI report represents the culmination of numerous studies that have attempted to assess and quantify the effects of releases from Rocky Flats, and how they impact the surrounding offsite areas. The data set collected for the OU 3 RFI/RI report is the most extensive and rigorously documented data set gathered to date. The RI data set serves to validate some of the previous studies while adding information to the overall site knowledge. The results of these studies indicate that the contaminants of concern for OU 3 (plutonium and americium) are relatively stable and immobile in surface soils and reservoir sediments, they occur at very low levels, and they represent little, if any, additional risk to human health and the environment. Given these considerations, additional investigations or remedial actions are not warranted for OU 3.

Because the data indicate that remedial actions will not be necessary for this OU, the next step toward closure of OU 3 will be the development of the Proposed Remedial Action Plan. The Proposed Plan will summarize the site risks, include public involvement in the decision making process, and an analysis of the preferred remedy.

By completing the RFI/RI report, Proposed Remedial Action Plan, and Record of Decision process, the Department of Energy, the regulatory agencies, and the surrounding communities will be able to make informed, confident, risk management-based decisions regarding the future of OU 3.

8.0 REFERENCES

Adriano, D. C., A. Wallace, and E. M. Romney, 1980, *Uptake of Transuranic Nuclides from Soil by Plants Grown under Controlled Environmental Conditions,* DOE/TIC-22800.

Allard, B. and J. Rydberg, 1983, "Behavior of Plutonium in Natural Waters," *Plutonium Chemistry,* ACS Symposium Series, 216, 1983.

Allen, L. E. and M. I. Litaor, 1995, *Analysis of Selected Metals in the Surficial Soils of OU 2.*

American Chemical Society (ACS), 1979, *Radioactive Waste in Geologic Storage (Abyssal Red Clay),* ACS Symposium Series.

Ames, L. L., Rai, D., and Serne, R. J., 1976, *A Review of Actinide-Sediment Reactions with Annotated Bibliography,* BNWL-1983.

Andelman, J. B. and T. C. Rozzell, 1970, "Plutonium in the Water Environment, I. Characteristics of Aqueous Plutonium," *Radionuclides in the Environment,* Advances in Chemistry Series, No. 93.

Arber Associates, 1982, *Standley Lake Water Quality Study for the City of Thornton and City of Westminster,* December.

Argonne National Laboratory (ANL), 1993, *Manual for Implementing Residual Radioactive Material Guidelines using RESRAD, Version 5.0,* September.

Arvada, 1994, *Arvada Department of Water and Environmental Quality Database.*

Advanced Sciences Incorporated (ASI), 1990, *Water-Yield and Water Quality Study of other Sources Tributary to Standley Lake and Great Western Reservoir, Rocky Flats Plant; Task 16 of the Zero-Offsite Water-Discharge Study, Final Report,* December.

Baes, C. F. and R. D. Sharp,, 1983, "A Proposal for Estimation of Soil Leaching Constants for Use in Assessment Models," *Journal of Environmental Quality,* Vol. 12, No. 1.

Battelle Pacific Northwest Laboratories (Battelle), 1981, *Radionuclide Concentrations in Reservoirs, Streams, and Domestic Waters near the Rocky Flats Installation,* April.

Bodek, I. (ed.) et al., 1988, *Environmental Inorganic Chemistry*, Pergamon Press, New York.

Brookins, D. G., 1988, *Eh-pH Diagrams for Geochemistry*, Springer-Verlay, New York.

Broomfield, 1991, *City of Broomfield Planning and Zoning Department, City of Broomfield Master Plan Land Use,* December.

Broomfield, 1992, *Sediment Sampling Summary Report, Great Western Reservoir, Broomfield, Colorado,* by Steve Hoffman, Enviro Check, Inc., April 1992.

Broomfield, 1993, City of Broomfield, Water Quality Services to EG&G Rocky Flats, Personal Communication, Subject: *City of Broomfield Water Treatment Facility,* February.

Brownlow, A. H., *Geochemistry,* Prentice-Hall, 1979.

Case, M., 1994, *Rocky Flats Nuclear Weapons Plant, Dose Reconstruction Project, Phase II, Task 4,* June.

CCBA, 1994, Cherry Creek Basin Authority to EG&G Rocky Flats, Personal Communication, Subject: *Sediment Survey of Cherry Creek Reservoir,* March.

CDA, 1993, Colorado Department of Agriculture to EG&G Rocky Flats, Personal Communication, Subject: *Colorado Agricultural Statistics,* April.

Colorado Committee on Environmental Information (CCEI), 1970, Subcommittee on Rocky Flats, *Report on the Rocky Flats Fire: Implications of Plutonium Releases to the Public Health and Safety,* January.

Colorado Department of Public Health and Environment (CDPHE), 1970-present,, *Monthly Environmental Surveillance Report for the Rocky Flats Plant,* current issue.

CDPHE, 1977, *Radioactive Soil Contamination (Cesium-137 and Plutonium) in the Environment near the Rocky Flats Nuclear Weapons Plant,* September.

CDPHE, 1989, *Municipal Sampling,* 3907E/1554E, June.

CDPHE, 1990a, CDPHE to EG&G Rocky Flats, Personal Communication, Subject: *Great Western Reservoir Sampling Program.*

CDPHE, 1990b, CDPHE to EG&G Rocky Flats, Personal Communication, Subject: *Standley Lake Water Quality Information.*

CDPHE, 1990c, *Rocky Flats Surface Soil Survey,* 1970—1989, February.

CDPHE, 1990d, *Standley Lake Fish Toxics Monitoring Report,* January.

CDPHE, 1992, *Reconstruction of Historical Rocky Flats Operations and Identification of Release Points,* August.

City of Westminster, 1991, *Standley Lake Projection Project, Results of Soil Sampling along the Potential Interceptor Canal.*

Cohen, R. Gilbert, D., and Wolaver, H., 1990, *$^{239,240}Pu$, ^{137}Cs and ^{210}Pb distributions in Colorado Front Range lake sediments—A report to the Rocky Flats Plant, Rockwell International, and EG&G: Golden, Colorado School of Mines.*

Coughtrey, P. J. et al., 1985, *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems,* Volume Four (29), "Plutonium," and Volume Five (31) "Americium."

Coughtrey, P. J. and M. C. Thorne, 1983, *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems.*

CSU, 1974. Colorado State University, *The Study of Plutonium in Aquatic Systems of the Rocky Flats Environs*, prepared by J. E. Johnson, S. Svalbery and D. Paine, Department of Animal Sciences and Department of Radiology and Radiation Biology, Fort Collins, Colorado, for Dow Chemical Company, Rocky Flats Division, Contract No. 41493-F, June 1974.

Davis, J. A. and D. B. Kent, 1990, "Surface Complexation Modeling in Aqueous Geochemistry," *Mineral-Water Interface Geochemistry, Reviews in Mineralogy,* Vol. 23, pp. 177-260.

Denver Regional Council of Governments (DRCOG), 1989, *DRCOG makes 1989 estimates of Metropolitan and Households,* September.

Dragun, J., *The Soil Chemistry of Hazardous Materials,* 1988.

United States Department of Energy (DOE), 1978, *Time Pattern of Offsite Plutonium Concentration from Rocky Flats Plant by Lake Sediment Analyses,* July.

DOE, 1980a, *Final Environmental Impact Statement, Rocky Flats Plant Site, Golden, Jefferson County, Colorado,* DOE/EIS-0064.

DOE, 1980b, *Determination of Distribution Coefficients for Plutonium, Range of Results for a Variety of Sediments in the Enewetak Lagoon using Lab and Field Experiments.*

DOE, 1984, *A Review and Analysis of Parameters for Assessing Transport of Environmental Releases of Radionuclides through Agriculture.*

DOE, 1986, *Comprehensive Environmental Assessment and Response Program, Phase I: Installation Assessment, Rocky Flats Plant,* April.

DOE, 1988, *Resource Conservation and Recovery Act, Postclosure Care Permit Application for United States DOE-Rocky Flats, Hazardous and Radioactive Mixed Wastes*, CO7890010526, October.

DOE, 1990, *Population, Economics, and Land Use for Rocky Flats Plant (1989),* August.

DOE, 1991a, *Standard Operating Procedures 5.0, Ecology,* April.

DOE, 1991b, *Final Past Remedy Report, Operable Unit No. 3—IHSS 199,* April.

DOE, 1991c, *EMD Operating Procedures Manual,* 5-21200-OPS.

DOE, 1991d, *Historical Information Summary and Preliminary Health Risk Assessment, Operable Unit No. 3—IHSS 200-202,* April.

DOE, 1992a, *RFI/RI Final Work Plan for OU 3 Rocky Flats Plant*, 21100-WP-OU3.1, February.

DOE, 1992b, *Rocky Flats Surface Water Management Plan,* March.

DOE, 1992c, *Environmental Assessment, Standley Lake Diversion Project*, January.

DOE, 1992d, *Draft Environmental Assessment Standley Lake Diversion Project.*

DOE, 1993a, *Background Geochemical Characterization Report,* September.

DOE, 1993b, *Technical Memorandum No. 1 to the Final RFI/RI Work Plan: Operable Unit 3,* April.

DOE, 1993c, *DOE Data Management Requirements.*

DOE, 1993d, *Area of Concern Report for OU 3,* September.

DOE, 1994a, *Site Environmental Report for 1993.*

DOE, 1994b, *Rocky Flats Sitewide Quality Assurance Project Plan for CERCLA Remedial Investigations/Feasibility Studies and RCRA Facility Investigations/Corrective Measures Studies Activities,* January.

DOE, 1994c, *Fiscal Year 1994 OU 3 Sediment Dating and Sedimentation Rates,* October.

DOE, 1994d, Technical Memorandum No. 4, *Human Health Risk Assessment Chemicals of Concern Identification, Operable Unit 3.*

DOE, 1994e, *CDPHE Conservative Screen Letter Report.*

DOE, 1995a, *1994 Population, Economics, and Land Use Database for Rocky Flats Environmental Technology Site,* March.

DOE 1995b, *Geochemical Characterization of Background Surface Soils: Background Soils Characterization Program,* May.

DOE, 1995c, Technical Memorandum No. 2, *Sitewide Conceptual Model.*

DOE 1995d, Technical Memorandum No. 3, *Ecological Contaminant of Concern Selection Techniques.*

Doesken, 1993, Doesken, R., Assistant State Climatologist, State of Colorado, to EG&G Rocky Flats, Personal Communication, Subject: *Climatology of the Rocky Mountain Region; winter soil conditions,* February.

Dow Chemical (Dow) et al., 1971-present, Annual Environmental Monitoring Reports for the Rocky Flats Plant (various titles and contractors), current issue.

Dow, 1971, *Committee Evaluation of Plutonium Levels in Soil Within and Surrounding USAEC Installation at Rocky Flats, Colorado,* RFP-INV-10, July.

Dow, 1972, *Soil Sampling east of Indiana Avenue,* Dow Product and Health Physics Research Service Report No. 317-72-186, November.

Dow, 1973, *Environmental Inventory—A Historical Summation of Environmental Incidents Affecting Soils at or near the United States AEC Rocky Flats Plant,* October.

Dow, 1974, *Survey of Reservoir Sediments,* August.

Dragun, J., 1988, *The Soil Chemistry of Hazardous Materials,* Hazardous Materials Research Institute.

Colorado Division of Water Resources (DWR), 1990, selected records for water wells in the vicinity of the SWMU 199 site east of the Rocky Flats Plant.

EG&G Rocky Flats, Inc. (EG&G), 1989, *Quality Assurance Project Plan Manual.*

EG&G, 1990a, *Draft Geologic Characterization Report,* January.

EG&G, 1990b, *1989 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant,* March.

EG&G, 1991a, *Rocky Flats Plant Site Environmental Report.*

EG&G, 1991b, *Operable Unit 3: Offsite Releases, Reservoirs,* EG&G Community Relations Information Bulletin, August.

EG&G, 1991c, *Draft Final Geological Characterization,* July.

EG&G, 1992, *Background Geochemical Characterization Plan,* September.

EG&G, 1993, *Rocky Flats Plant Site Environmental Report.*

EG&G, 1994a, *Practical Suggestions to Users of RFEDS Data,* March.

EG&G, 1994b, *Evaluation of ERM Data for Useability in Final Reports,* 2-G32-ER-ADM-0802, October.

EG&G, 1994c, *Rocky Flats Plant Site Environmental Report.*

EG&G, 1995a, *Geologic Characterization Report for the Rocky Flats Environmental Technology Site, Volume I of the Sitewide Geoscience Characterization Study,* March.

EG&G, 1995b, *Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site, Volume II of the Sitewide Geoscience Characterization Study,* March.

United States Environmental Protection Agency (EPA), 1971, *Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Golden, Colorado,* April,

EPA, 1973, *Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Golden, Colorado, Part II,* December.

EPA, 1975, *Plutonium Levels in the Sediment of Area Impoundments Environs of the Rocky Flats Plutonium Plant—Colorado*, PB-255-572, February.

EPA, 1987, *A Compendium of Superfund Field Operations Methods, Volumes 1 and 2,* EPA 540/P-87/001b.

EPA, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA 540/G-89/004, OSWER Directive 9355.3-01, October.

EPA, 1989a, *Risk Assessment Guidance for Superfund, Volume I: Part A, Human Health Evaluation Manual,* EPA/540/1-89/002, December.

EPA, 1989b, *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual, Interim Final,* EPA/540/1-89/001, December.

EPA, 1989c, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities.*

EPA, 1989d, *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference Document.*

EPA, 1990, *Guidance for Data Useability in Risk Assessment (Part A),* EPA/540/6-90/008, October.

EPA, 1991, *Rocky Flats Interagency Agreement*, January.

EPA, 1992a, *Baseline Risk Assessment Landfill Solids and Landfill Gas Operable Units 2 and 3, Soils and Surface Water; and Sediment Operable Units 4 and 5, Sediment,* December.

EPA, 1992b, *Framework for Ecological Risk Assessment,* EPA/630/R-92/001.

EPA, 1993, *Storage and Retrieval of Water Quality Information (STORET) Database,* December.

EPA, 1994a, *Storage and Retrieval of Water Quality Information (STORET) Database,* July.

EPA, 1994b, *Ecological Risk Assessment Guidance for Superfund.*

Faure, G., 1991, *Principles and Applications of Inorganic Geochemistry,* MacMillian Publishing Company, New York.

Friesen, H. N., 1992, *Summary of Nevada Applied Ecology Group and Correlative Programs,* DOE/NV-357.

Hansen, W. C. (ed.), 1980, Transuranic Elements in the Environment, DOE/TIC-22800.

Heit et al., 1984, *Evidence of Deposition of Anthropogenic Pollutants in Remote Rocky Mountain Lakes, Water, Air, and Soil Pollution* 22, pp. 403-416.

Hiatt, G. S., 1977, *Plutonium Dispersal by Mule Deer at Rocky Flats, Colorado,* Master's Thesis, Colorado State University, Fort Collins, CO.

Higley, K. and R. Kuperman, 1995, *Radiological Benchmarks for Wildlife at Rocky Flats Environmental Technology Site.*

Hume, 1978, Hume, M. W., Rockwell International, to Illsley, C. T., Internal Letter, Subject: *Comparison of Air Sampler Stations,* November.

Hurr, R. T., 1976, *Hydrology of a Nuclear-Processing Plant Site, Rocky Flats, Jefferson County, Colorado,* U.S. Geological Survey Open-File Report 76-268.

Hydro-Search, Inc., 1985, *Hydrogeologic Characterization of the Rocky Flats Plant,* Project No. 1520, December.

Ibrahim, S. A. and F. W. Wicker, 1992, Progress Report for Radiological Investigations at Rocky Flats, EG&G-RF/ASC83749/CSU.

Illsley, C. T., 1977, *Results of Special Soil Samples Collected Adjacent to the Rocky Flats Plant Site,* September.

Illsley, C. T., 1979, *Results of Special Soil Samples Collected Adjacent to the Rocky Flats Plant Site,* Rockwell International, Environmental Analysis and Control, ES-376-77-201, 7 September.

Illsley, C. T., 1987a, *Soil Sample Collection and Analysis for Plutonium on Lands Adjacent to Great Western Reservoir for the City of Broomfield,* January.

Illsley, C. T., 1987b, *Remedial Action Program on Jefferson County Open Space Land in Section 7, T2S, R69W, South of Great Western Reservoir,* October.

Illsley, C. T. and M. W. Hume, 1979, Plutonium Concentrations in Soil on Lands Adjacent to the Rocky Flats Plant, March.

Johnson, C. J., 1981, *Cancer Incidence in an Area Contaminated with Radionuclides near a Nuclear Installation,* Ambio, 10:176-182.

Krey, P. W., 1976, *Remote Plutonium Contamination and Total Inventories from Rocky Flats,* Health Physics, 30:209-214.

Krey, P. W. and E. P. Hardy, 1970, *Plutonium in Soil around the Rocky Flats Plant,* Atomic Energy Commission Report, HASL-235.

Litaor, M. I., 1995, *Vertical Distribution of Actinides in the Soils of Operable Unit 3.*

Litaor et al., 1995, *Comprehensive Appraisal of Plutonium-239 and -240 in Soils of Operable Units 1, 2, 3: A Basis for Risk Analysis.*

Litaor, M. I. and L. Allen, 1995, *A Comprehensive Appraisal of Americium-241 in Soils of Operable Units 1, 2, and 3.*

Little, C. A., 1980, *Plutonium in a Grassland Ecosystem*, PP 420-440.

Loser, R. W. and R. L. Tibbals, 1972, *Soil Sampling east of Indiana Avenue,* November.

Montgomery, J. M., 1985, *Water Treatment Principles and Design,* New York.

Midwest Research Institute (MRI), 1994, *OU 3 Wind Tunnel Study,* January.

U.S. Nuclear Regulatory Commission, (NRC), 1984, *De Minimus Waste Impact Analysis Methodology,* NUREG/CR-3585, February.

Rai, D. and J. M. Zachara, 1984, *Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration*, Vol. 1, Electric Power Institute, Palo Alto, CA.

Rees, T. F. et al., 1978, "Dispersion of Plutonium from Contaminated Pond Sediments," *Environmental Science and Technology, 12:1085*, September.

Robson, S. G. et al., 1981, *Geologic Structure, Hydrology, and Water Quality of the Laramie-Fox Hills Aquifer in the Denver Basin, Colorado*, U.S. Geological Survey Hydrologic Atlas, HA-650.

Rockwell International (Rockwell), 1979a, *Results of Special Soil Samples Collected Adjacent to the Rocky Flats Plant Site*, ES-376-77-201, November.

Rockwell, 1979b, *Plutonium Concentrations in Soil on Lands Adjacent to the Rocky Flats Plant*, LPR-1, March.

Rockwell, 1979c, *Great Western Reservoir Spillway Sediment Sampling Program Phase I Report*, May.

Rockwell, 1980, *Great Western Reservoir Spillway Sediment Sampling Program Phase II Report*, August.

Rockwell, 1984, *Standley Lake Sediment Sample Collection Summary, August 1984*, September.

Rockwell, 1985a, *Disclosure to the City of Broomfield*, January.

Rockwell, 1985b, *Great Western Reservoir Sediment Cores*, February.

Rockwell, 1986, *Draft Work Plan, Geological and Hydrological Site Characterization.*

Rockwell, 1988a, *Remedial Investigation and Feasibility Study Plans for Low-Priority Sites*, June.

Rockwell, 1988b, *Remedial Action Air Sampling Results—1987*, Data Table.

Rockwell, 1989a, *Radioactive Ambient Air Monitoring Data*, Data Table.

Rockwell, 1989b, *1988 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant*, March.

Roxbough, L. S., 1987, *Geology of High-Level Nuclear Waste Disposal: An Introduction*, London.

Schnoor, K., 1991, Schnoor, K., City of Broomfield, to Chemrisk, Personal Correspondence, Subject: *Storage Capacity of Great Western Reservoir*, June 4.

Seed, J. R. et al., 1971, Committee Evaluation of Plutonium Levels in Soil within and Surrounding USAEC Installation at Rocky Flats, Colorado, July.

Standley Lake Cities, 1992, *Draft Environmental Assessment, Standley Lake Diversion Project*, January.

Terry, R. W., 1991, *Contamination of Surface Soils in Colorado by Plutonium, 1970—1989: Summary and Comparison of Plutonium Concentrations in Soil in the Rocky Flats Plant Vicinity and Eastern Colorado*, April.

Tipton and Kalmbach, Inc. (Tipton), 1989, *Interim Engineer Report: Change of Water Rights for the City of Westminster*, Case Nos. 86CW397, 88W267, and 89CW129, Repository Document PO-639.
United States Department of Agriculture (USDA), 1980, *Soil Survey of Golden Area, Colorado.*

United States Fish and Wildlife Service, 1981a, *Draft Refuge Manual, Service Policy, Operating Guidelines and Technical References for the Management of the National Wildlife Refuge System,* 7 RM 11. U.S.D.I. Fish and Wildlife Services.

United States Fish and Wildlife Service, 1981b, *Standards for the Development of Habitat Suitability Index Models,* 103 ESM. U.S.D.I. Fish and Wildlife Service.

United States Geological Survey (USGS), 1987, *Hydrology of Area 59, Northern Great Plains and Rocky Mountain Coal Provinces, Colorado and Wyoming,* Open File Report 85-153, January.

Wallace, A., and E. M. Romney, 1972, *Radioecology and Ecophysiology of Desert Plants at the Nevada Test Site,* TID-25954.

Whicker, F. W., 1975, *Radioecology of National Ecosystems in Colorado.*

Whicker, F. W., 1979, *Radioecology of Natural System.*

Whicker, F. W., 1980, "Ecological Effects of Transuranics in the Terrestrial Environment," *Transuranic Elements in the Environment,* DOE/TIC-22800.

Whicker, F. W. and S. A. Ibrahim, 1993, *Radiological Investigations at Rocky Flats,* April.

Whicker, F. W., S. A. Ibrahim, and L. Fraley, 1991, *Radiological Investigations at Rocky Flats,* EG&G-RF/ASC 49074 WS/CSU-02.

Wildung, R. E. and T. R. Garland, 1980, "The Relationship of Microbial Processes to the Fate and Behavior of Transuranic Elements in Soils, Plants, and Animals,"*Transuranic Elements in the Environment,* DOE/TIC-22800.

Yamamoto, A., 1986, *Organotransition Metal Chemistry: Fundamental Concepts and Applications.*

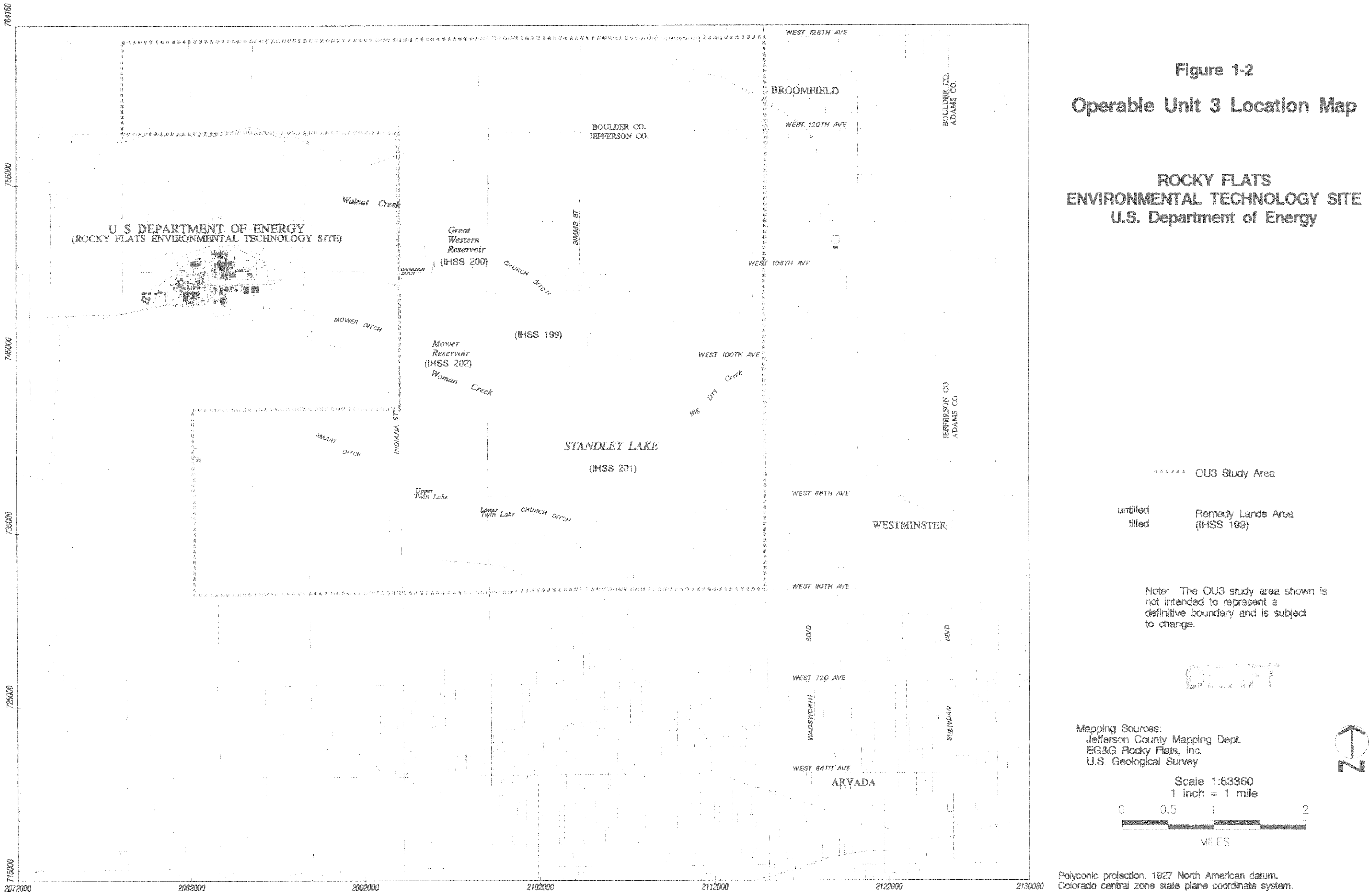


Figure 1-2

Operable Unit 3 Location Map

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Note: The OU3 study area shown is not intended to represent a definitive boundary and is subject to change.

DRAFT

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats, Inc.
U.S. Geological Survey

Scale 1:63360
1 inch = 1 mile

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

MAP FILE NAME: FIG1-2.EPS
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DRAWN BY: M. Campbell September 25, 1995
APPROVED BY:
Draft RI Report
Fig 1-2

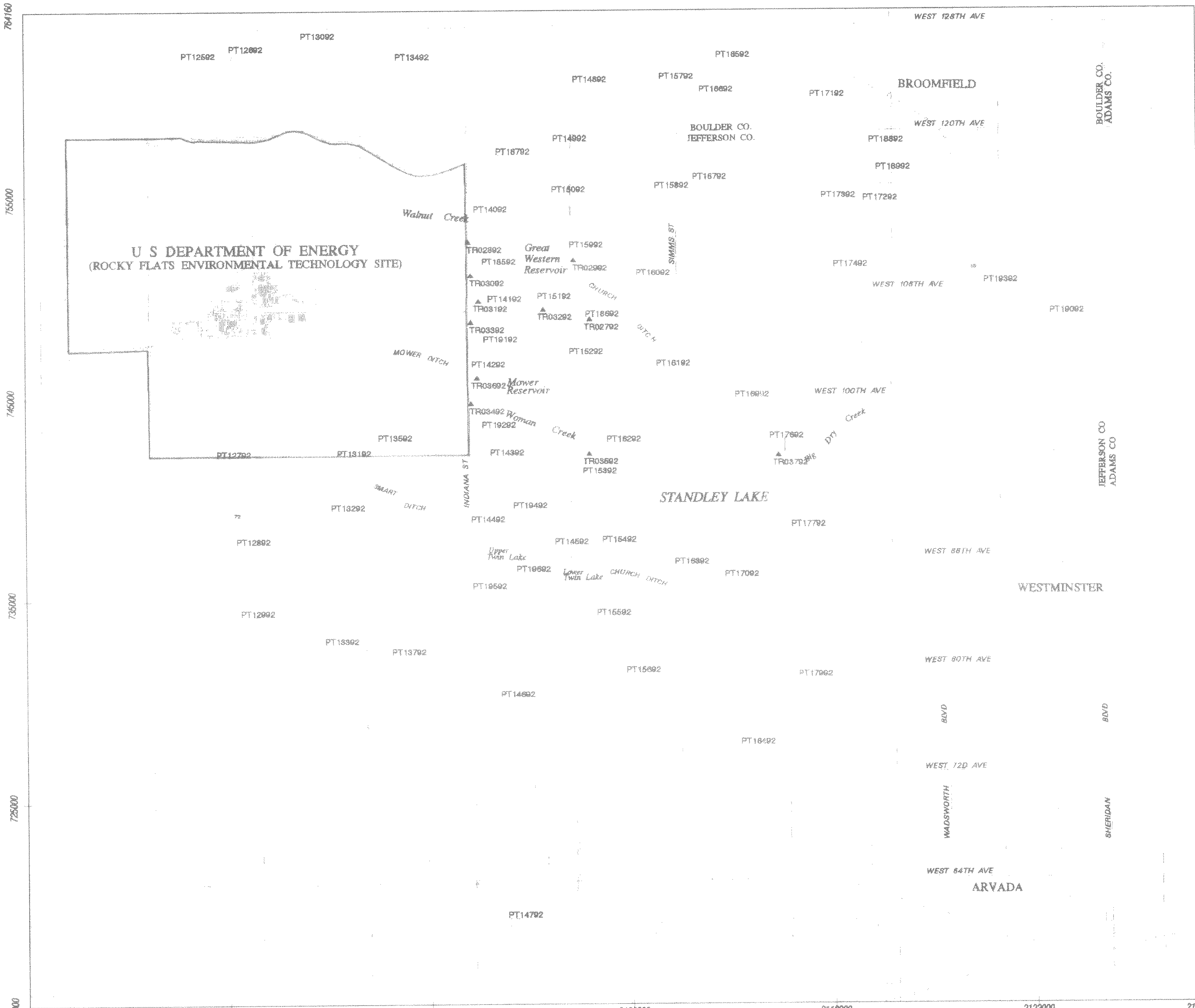

Figure 2-1

Surface Soil Sample Locations
Operable Unit 3
IHSS 199 Surface Soils Sampling Area

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Surface Soil Plot

▲ Trench Sample Locations

DRAFT

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1:63360
1 inch = 1 mile

0 0.5 1 2
MILES

N

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

Draft RI Report
Fig 2-1

September 22, 1995

DRAWN BY: D Moreno
APPROVED BY:

MAP FILE NAME: FIG2-1.EPS
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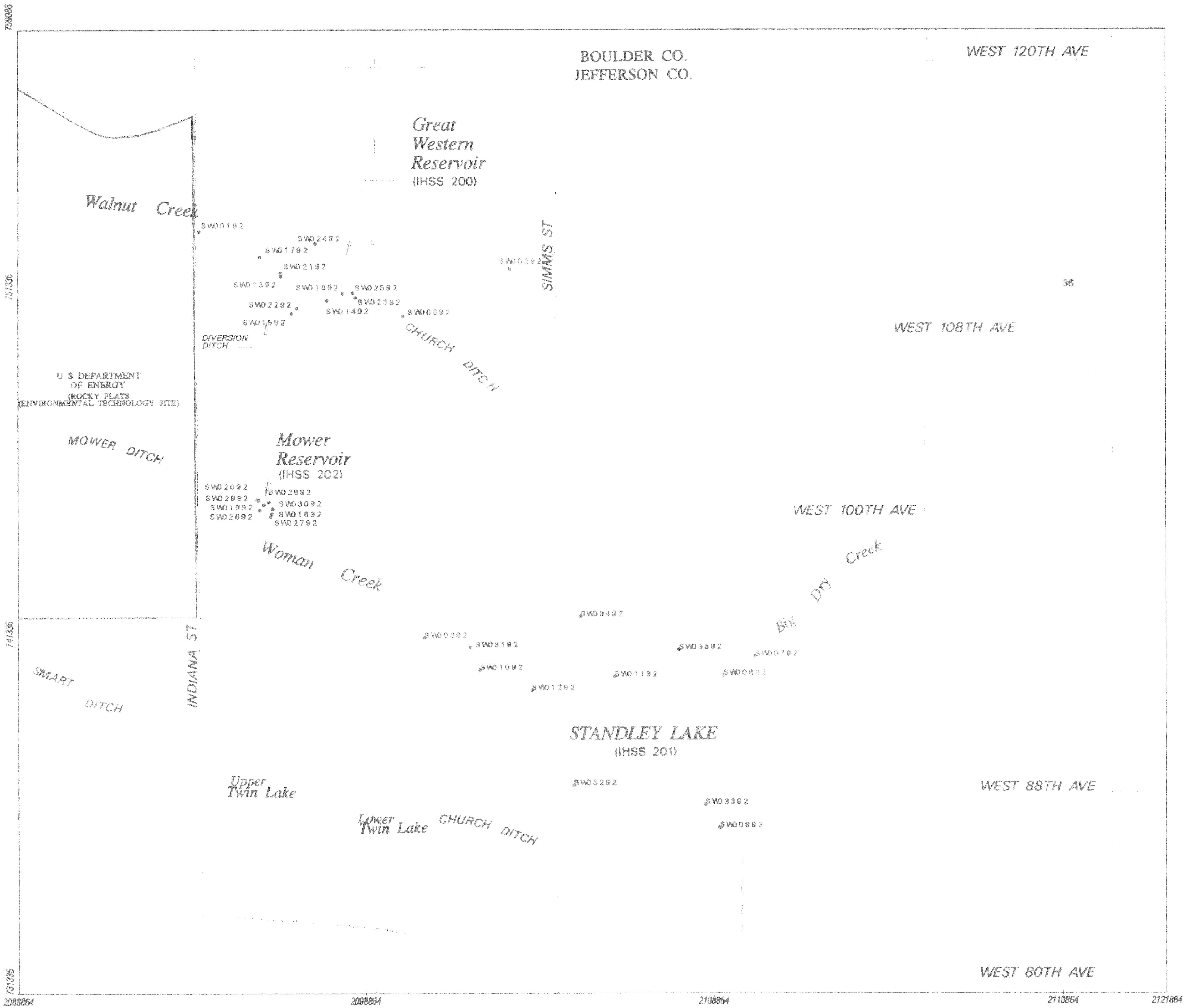

Figure 2-2

Surface Water Sample Locations Operable Unit 3

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE U.S. Department of Energy

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1:36000
1 inch = 3000 Feet

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

MAP FILE NAME: FIG2-2.EPS
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DRAWN BY: M. Campbell
APPROVED BY:

September 25, 1995

Draft RI Report
Fig 2-2

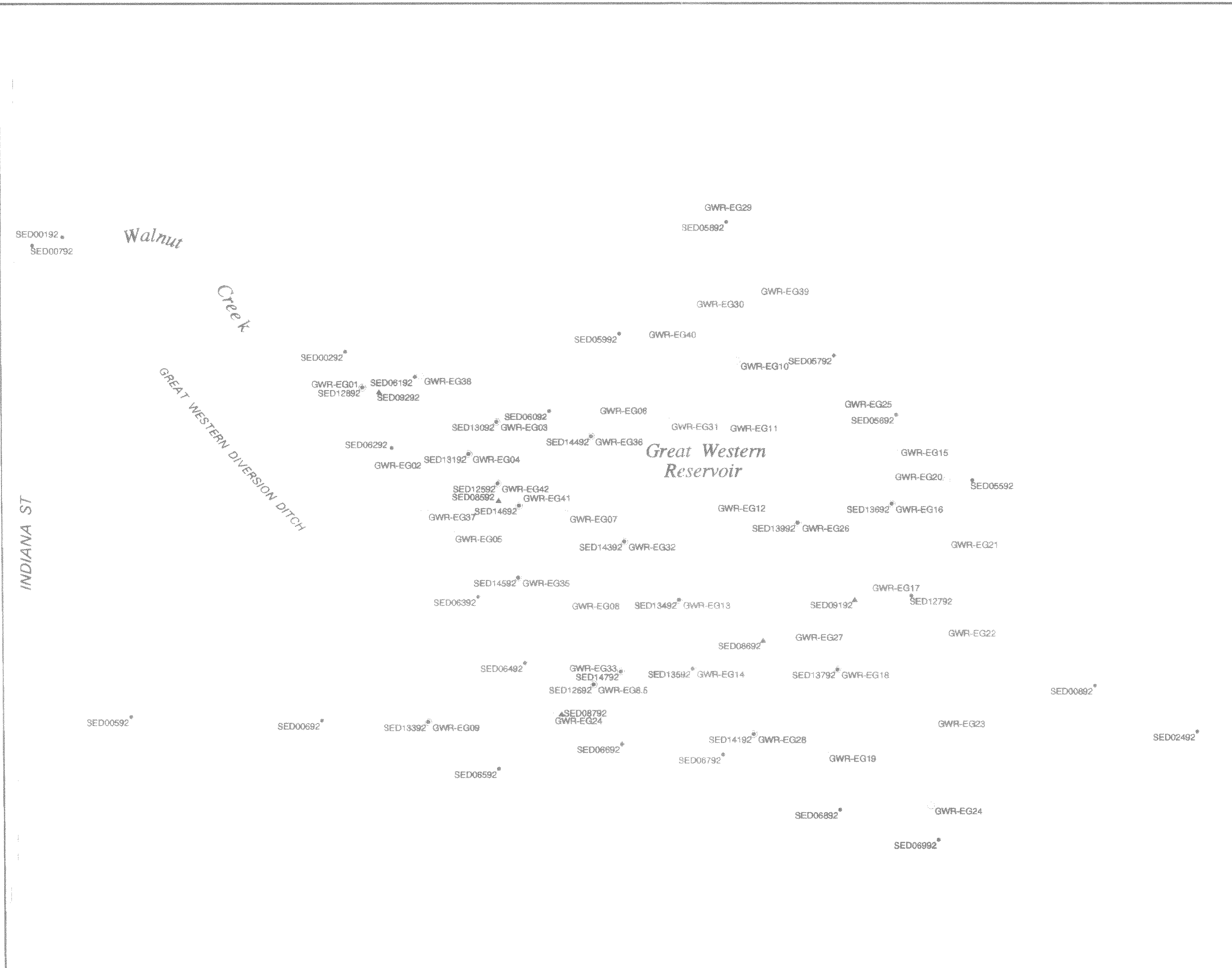

Figure 2-3

Sediment Grab and Core Sample Locations
Operable Unit 3

IHSS 200 Great Western Reservoir

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

- 1992 Sediment Grab/Core Sample Location
- ▲ 1992 Sediment Core Sample Location
- 1992 Sediment Grab Sample Location
- 1983/84 Sediment Sample Location

DRAFT

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1 : 6000
1 inch = 500 ft

0 250 500 1000
SCALE IN FEET

N

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

U. S. DEPARTMENT OF ENERGY

(ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE)

MAP FILE NAME: FIG2-3.EPS
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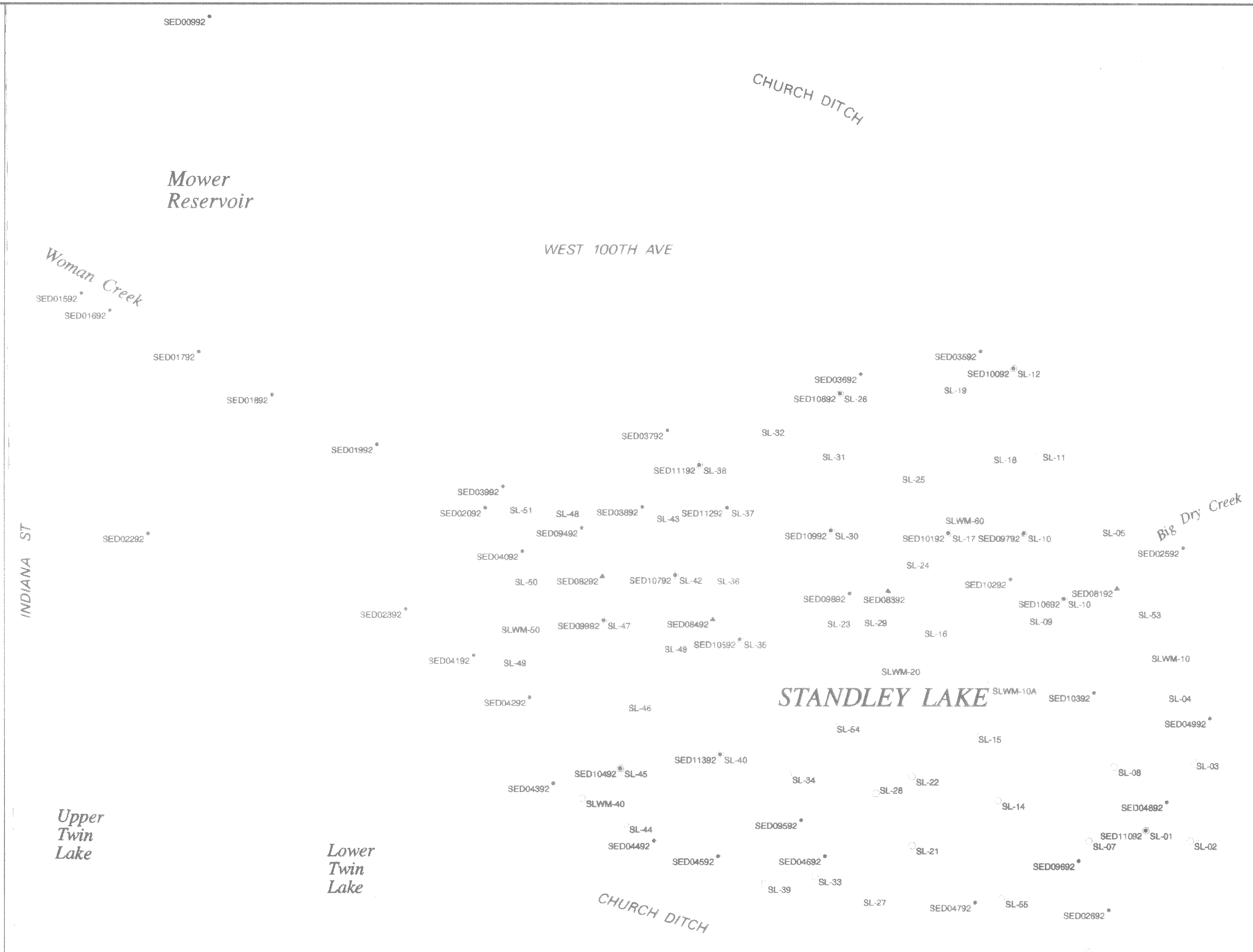
DRAWN BY: M. Campbell
APPROVED BY:

September 22, 1995
RI

754500
749600
2093700
2100200



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DRAWN BY: M. Campbell
APPROVED BY:

September 22, 1995
RI

Figure 2-4

Sediment Grab and Core Sample Locations
Operable Unit 3

IHSS 201 Standley Lake

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

- • 1992 Sediment Grab/Core Sample Location
- ▲ 1992 Sediment Core Sample Location
- • 1992 Sediment Grab Sample Location
- 1983/84 Sediment Sample Location

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1 : 15840
1 inch = 1320 ft or 0.25 mi

0 500 1000 2000
SCALE IN FEET

N

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

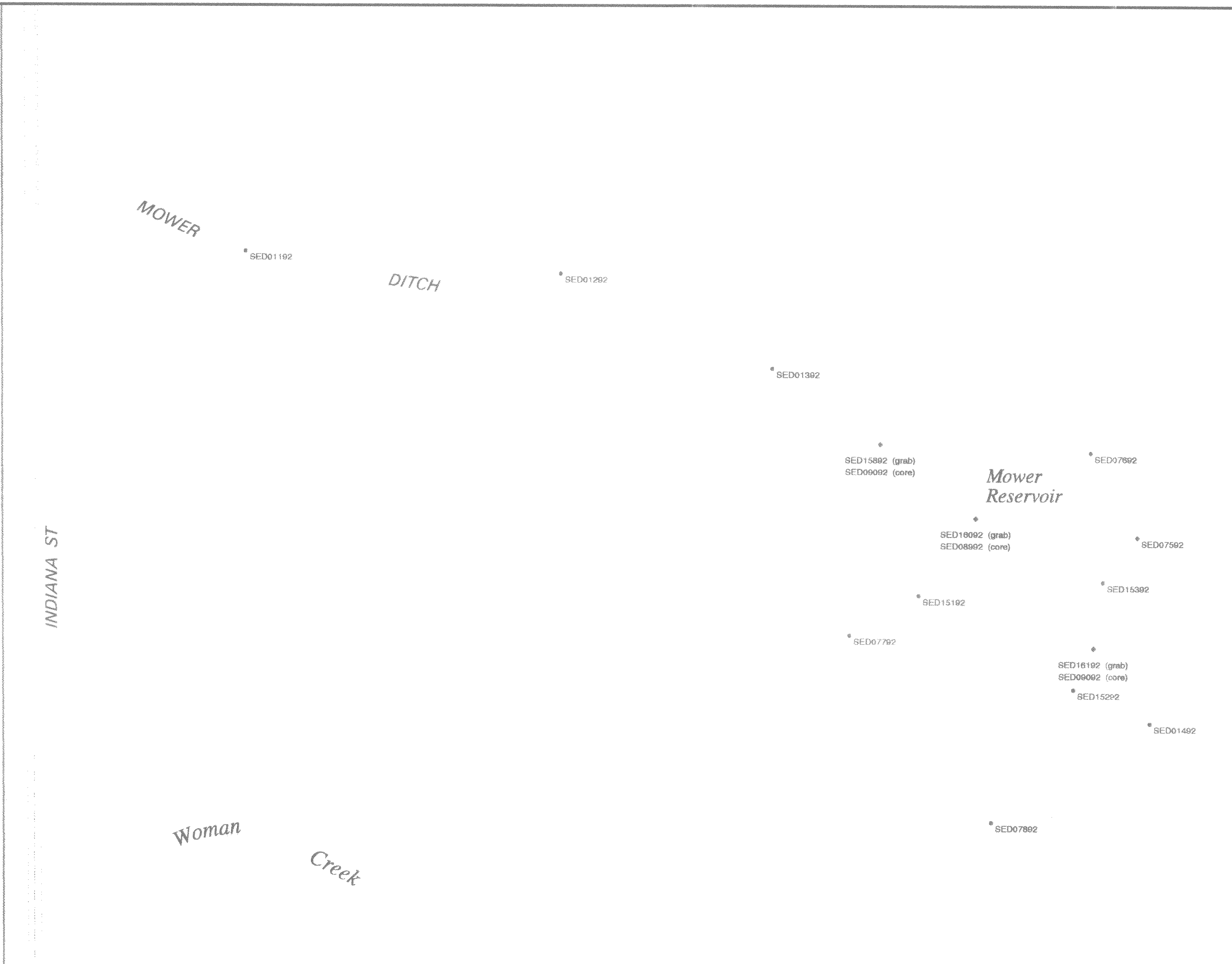

Figure 2-5

Sediment Grab and Core Sample Locations Operable Unit 3

IHSS 202 Mower Reservoir

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

- ◆ 1992 Sediment Grab/Core Sample Location
- ▲ 1992 Sediment Core Sample Location
- • 1992 Sediment Grab Sample Location

Note: No sediment samples were collected in Mower Reservoir as part of the 1983/84 sampling event.

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1 : 2400
1 inch = 200 ft

0 100 200 400
SCALE IN FEET

N

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

2093900
2096500
744500

U.S. DEPARTMENT OF ENERGY (ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE)

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Draft RI Report
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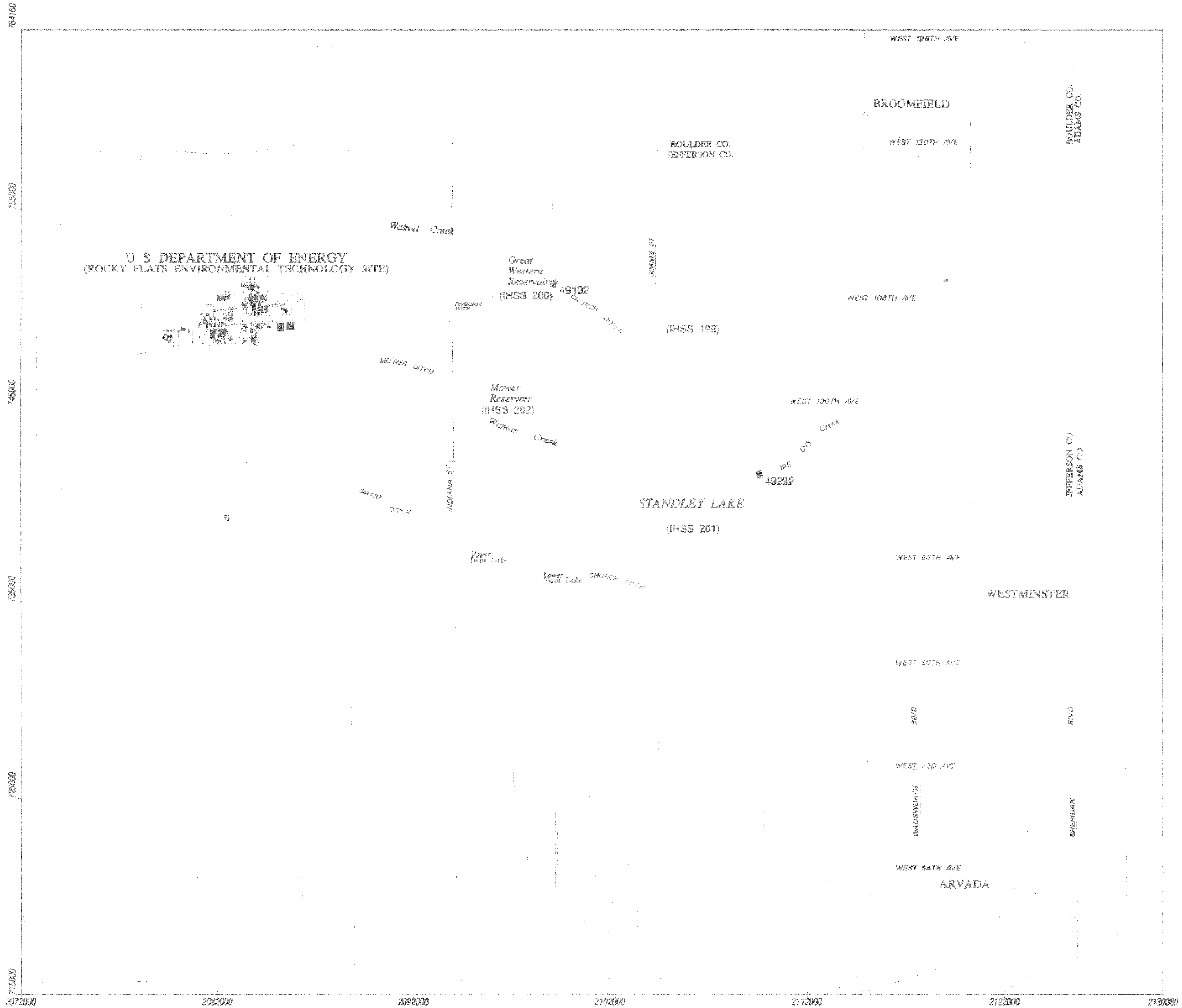

Figure 2-6

Ground Water Sample Locations
Operable Unit 3

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

● Ground Water Sample Location

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats, Inc.
U.S. Geological Survey

Scale 1:63360
1 inch = 1 mile

0 0.5 1 2
MILES

N

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

MAP FILE NAME: FIG2-6.EPS
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DRAWN BY: M Campbell
APPROVED BY:

September 25, 1995

Draft RI Report
Fig 2-6

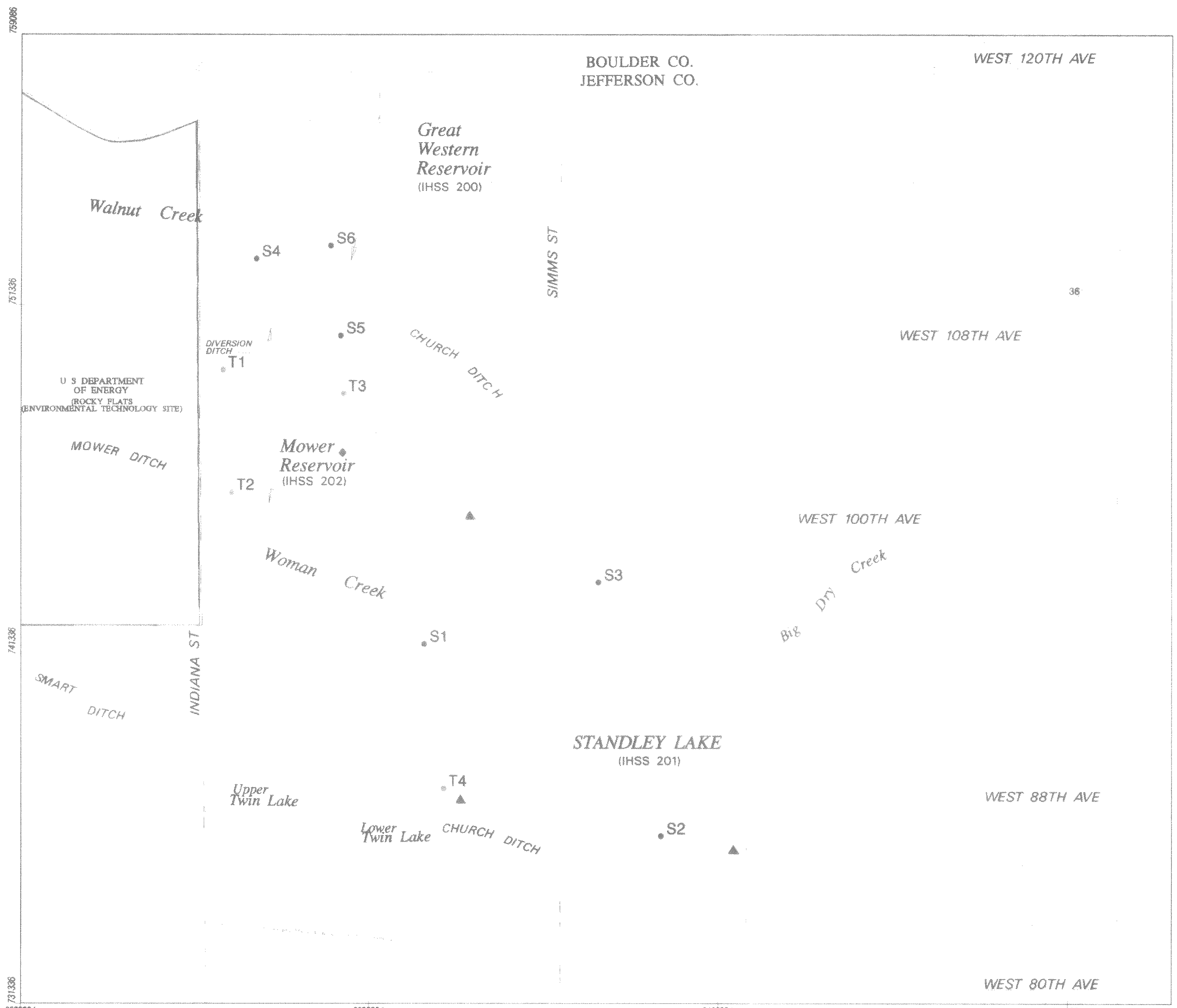

Figure 2-7

Air Sampling Test Sites Operable Unit 3

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE U.S. Department of Energy

Legend

- ● Wind Tunnel location (shoreline)
- ● Wind Tunnel location (Terrestrial)
- ◆ Meteorological Monitoring Station
- ▲ Ultra High-Vol. Air Monitoring Station

DRAFT

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1:36000
1 inch = 3000 Feet

0 1500 3000 6000
SCALE IN FEET

N

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

MAP FILE NAME: FIG2-7.EPS
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DRAWN BY: D Moreno
APPROVED BY:
September 22, 1995
Draft RI Report
Fig 2-7

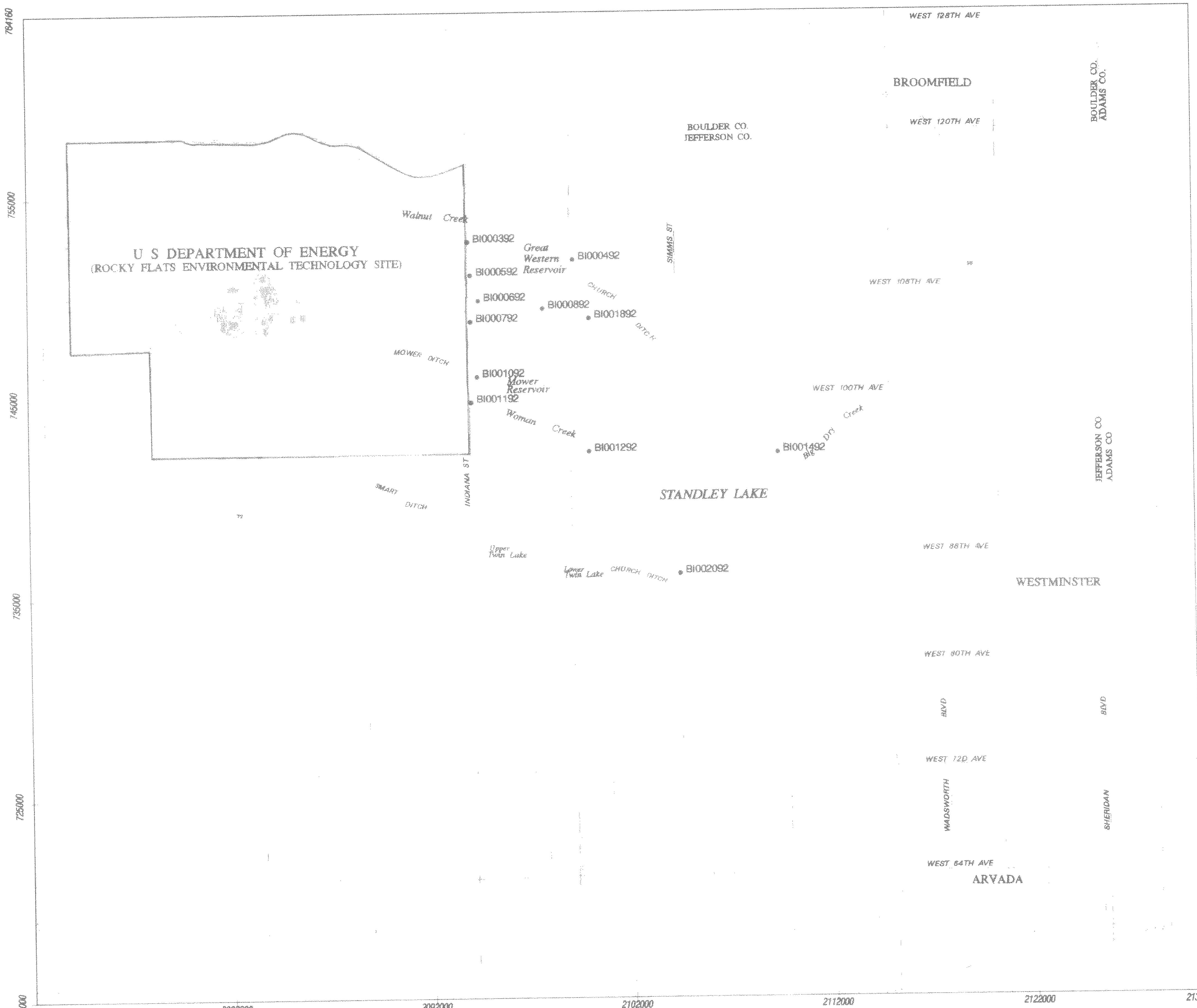

Figure 2-8

Terrestrial Sample Locations
Operable Unit 3
IHSS 199 Surface Soils Sampling Area

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

• Terrestrial Sample Location

DRAFT

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

N

Scale 1:63360
1 inch = 1 mile

0 0.5 1 2
MILES

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

MAP FILE NAME: FIG2-8.EPS
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DRAWN BY: D. Moreno
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September 22, 1995
RI Report

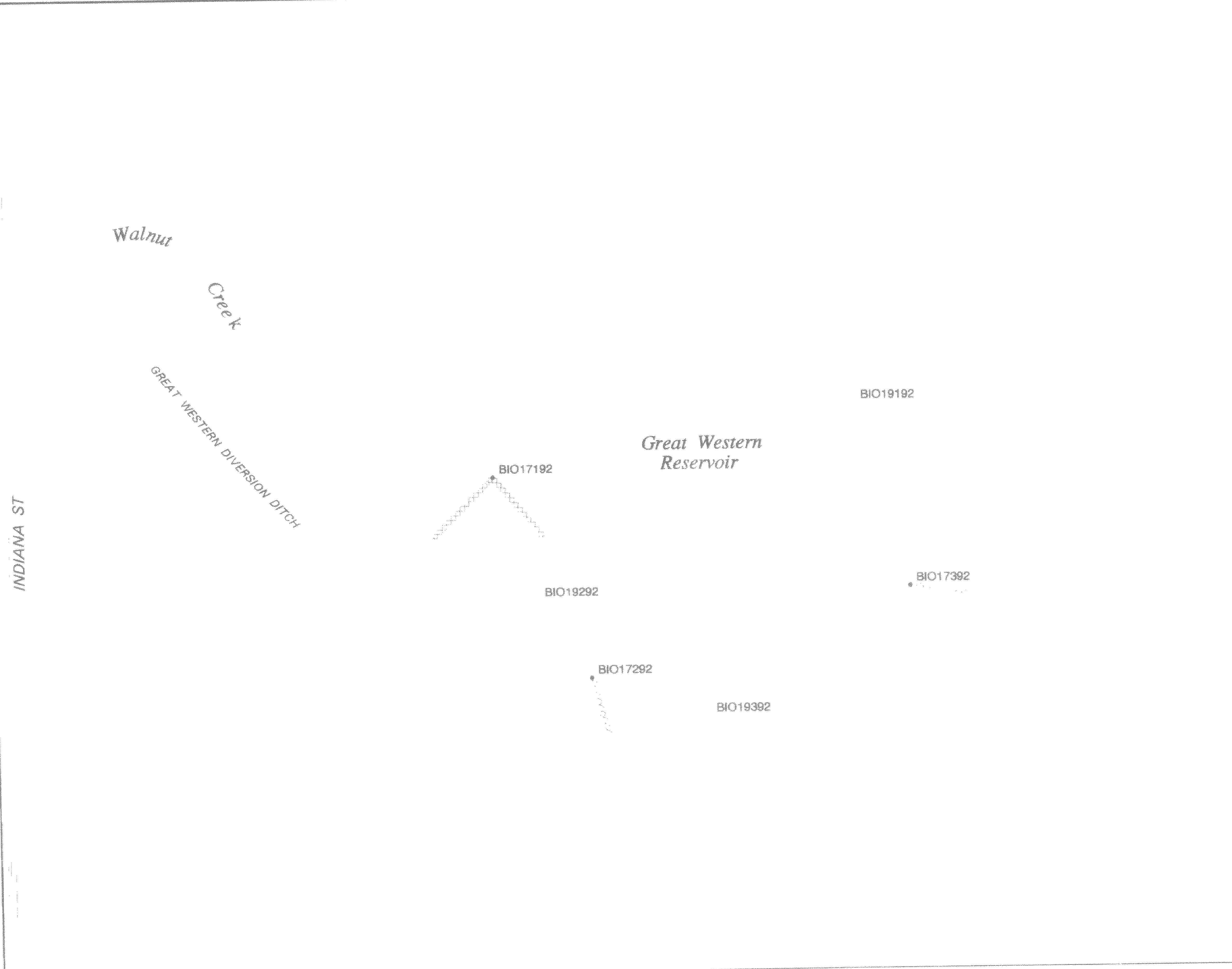

Figure 2-9

Aquatic Biological Sample Locations
Operable Unit 3
IHSS 200 Great Western Reservoir

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

DRAFT

- Biological sample location (Benthos, Surface Water and Sediment)
- Approx. Periphyton sample location
- Approx. Bioassay sample location
- Approx. Gill Net location

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey
CH2M HILL, Inc.

Scale 1 : 6000
1 inch = 500 ft

0 250 500 1000
SCALE IN FEET

N

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

U. S. DEPARTMENT OF ENERGY
(ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE)

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APPROVED BY:
September 25, 1995
Draft RI Report
Figure 2-9

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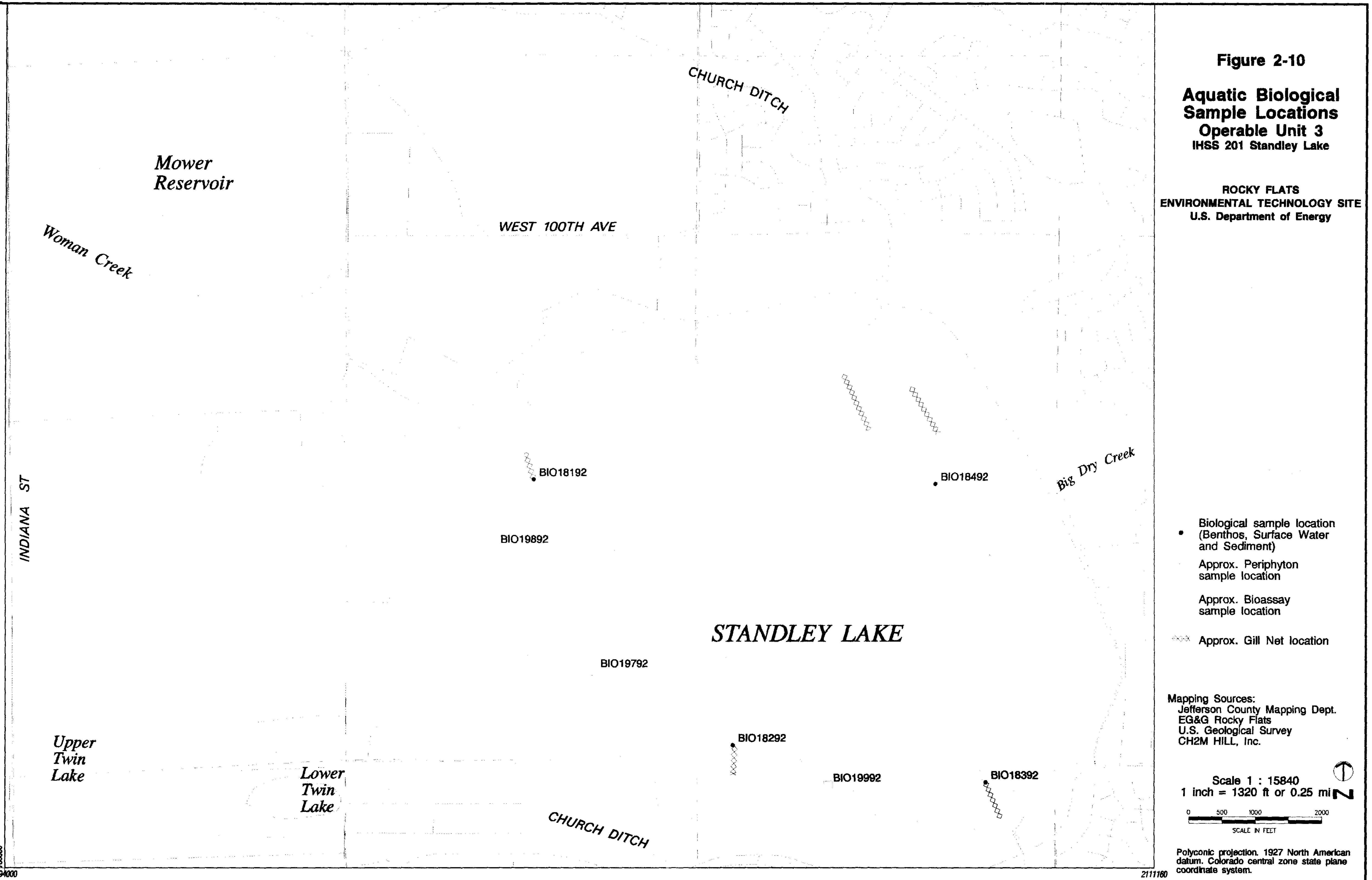

Figure 2-10

Aquatic Biological Sample Locations
Operable Unit 3
IHSS 201 Standley Lake

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey
CH2M HILL, Inc.

Scale 1 : 15840
1 inch = 1320 ft or 0.25 mi

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

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2093900

DRAWN BY: M. Campbell | October 04, 1995 | Draft RI Report
APPROVED BY: | | Figure 2-11

U.S. DEPARTMENT OF ENERGY (ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE)

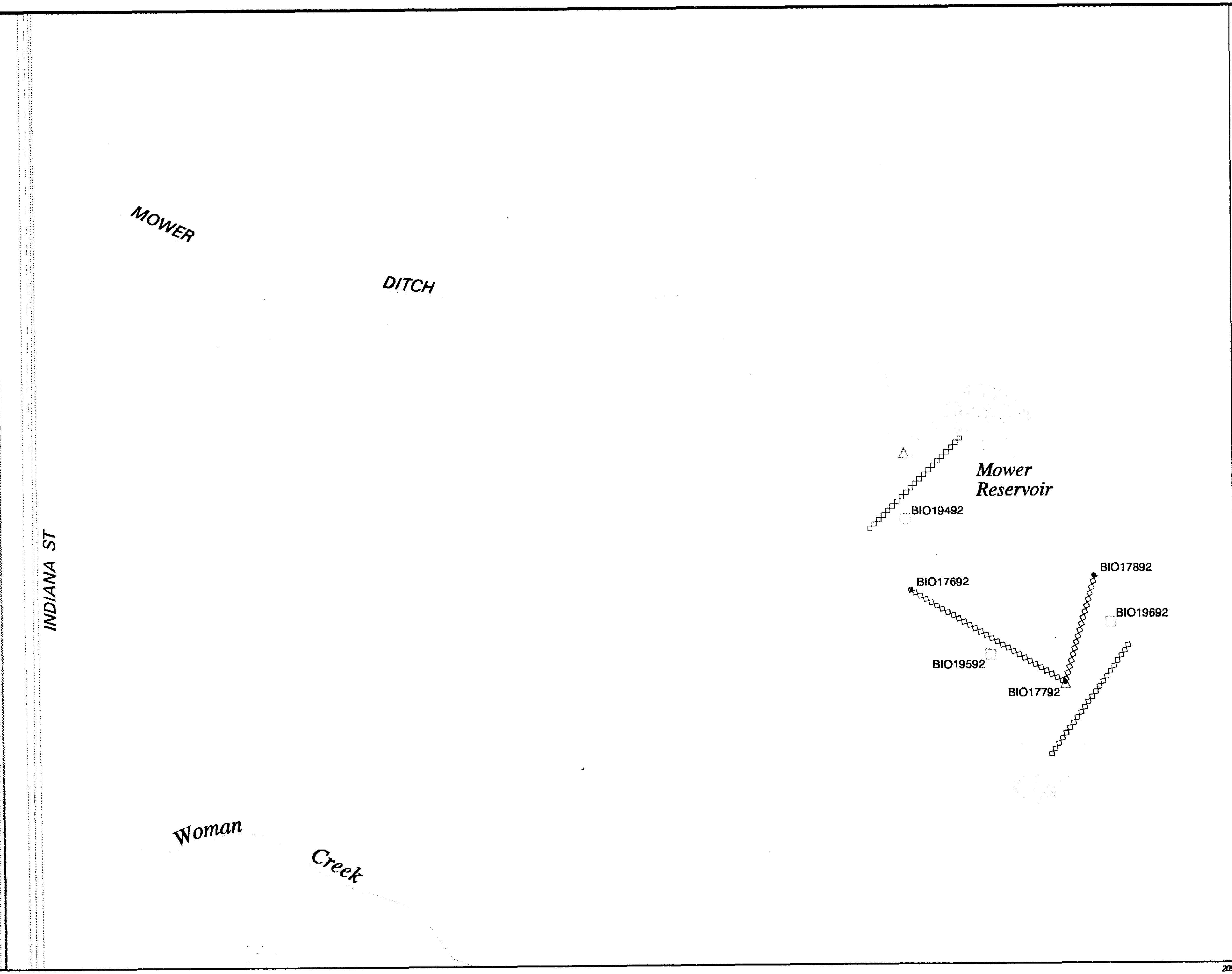

Figure 2-11

Aquatic Biological Sample Locations
Operable Unit 3
IHSS 202 Mower Reservoir

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

- • Biological sample location (Benthos, Surface Water and Sediment)
- □ Approx. Periphyton sample location
- △ Approx. Bioassay sample location
- ◊◊◊ Approx. Gill Net location

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey
CH2M HILL, Inc.

Scale 1 : 2400
1 inch = 200 ft

N

0 100 200 400
SCALE IN FEET

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

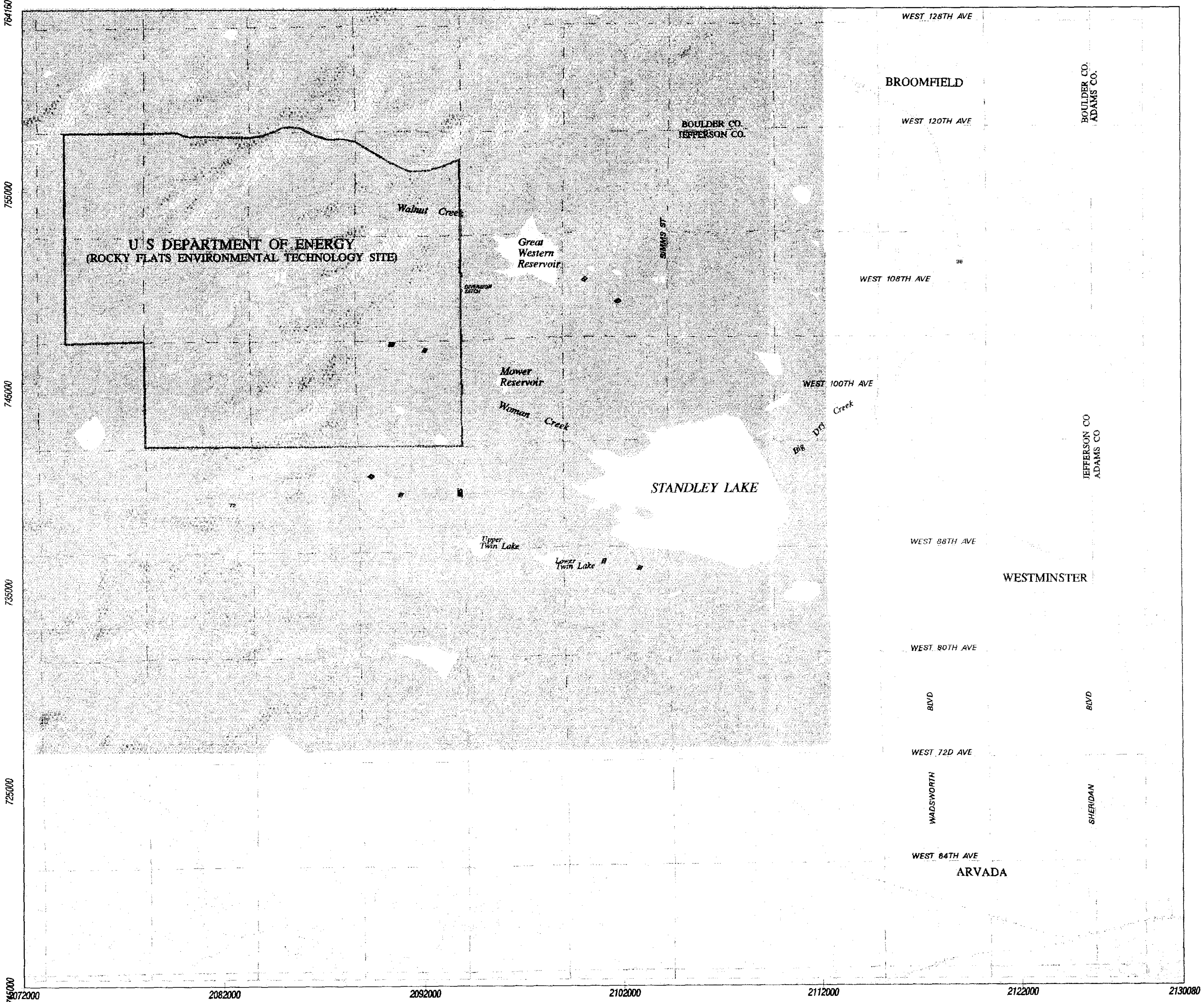

Figure 3-1

Topography
Operable Unit 3

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1:63360
1 inch = 1 mile

DRAFT

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

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Draft

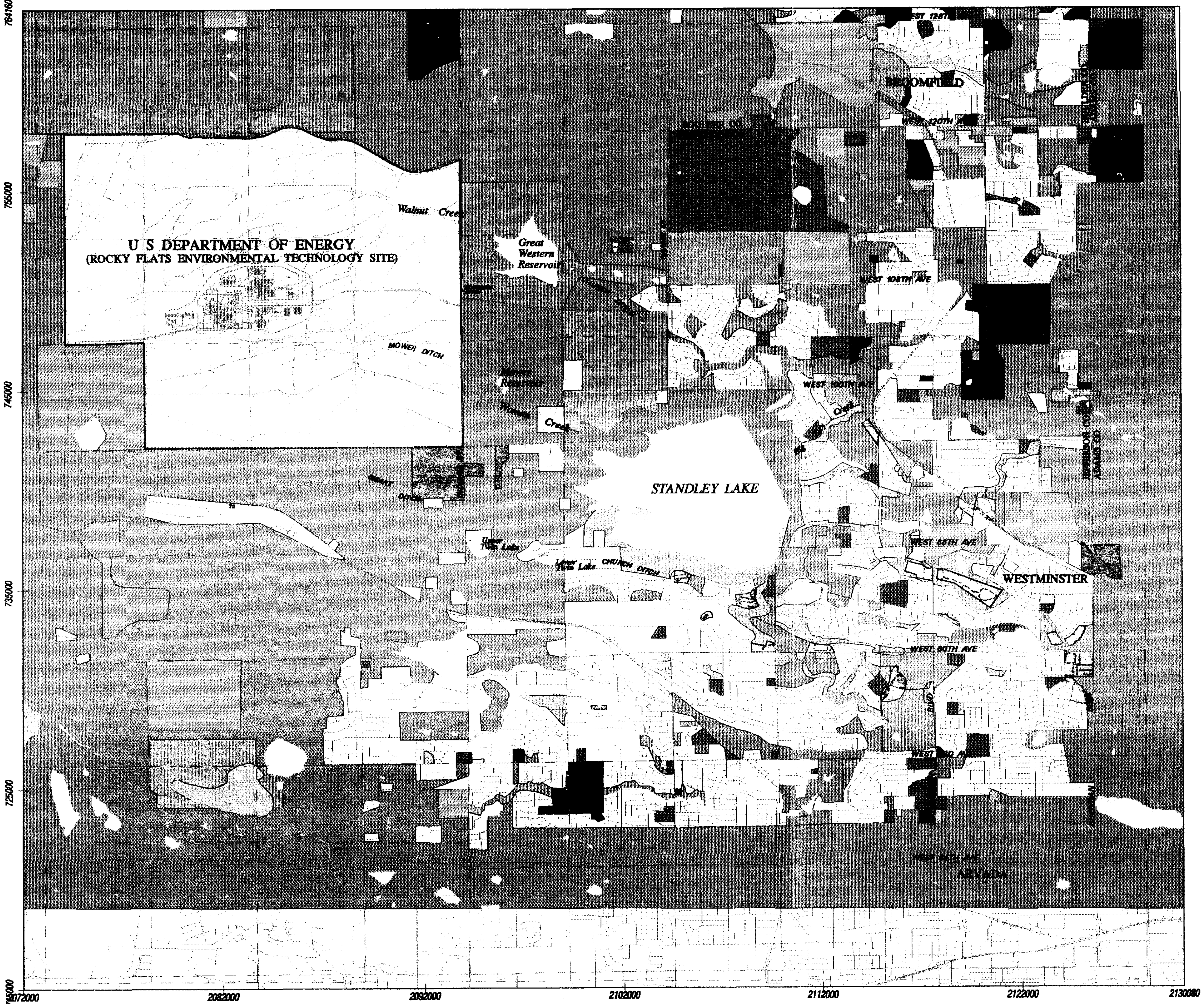

Figure 3-5

Existing Land Use
Operable Unit 3

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

- Industrial
- Commercial
- Residential
- Multi-Family Residential
- Water
- Institutional
- Parks/Open Space
- Agricultural
- Unclassified
- Comm/Resid Mix
- Comm/Ind/Res Mix

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

N

Scale 1:63360
1 inch = 1 mile

0 0.5 1 2

MILES

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

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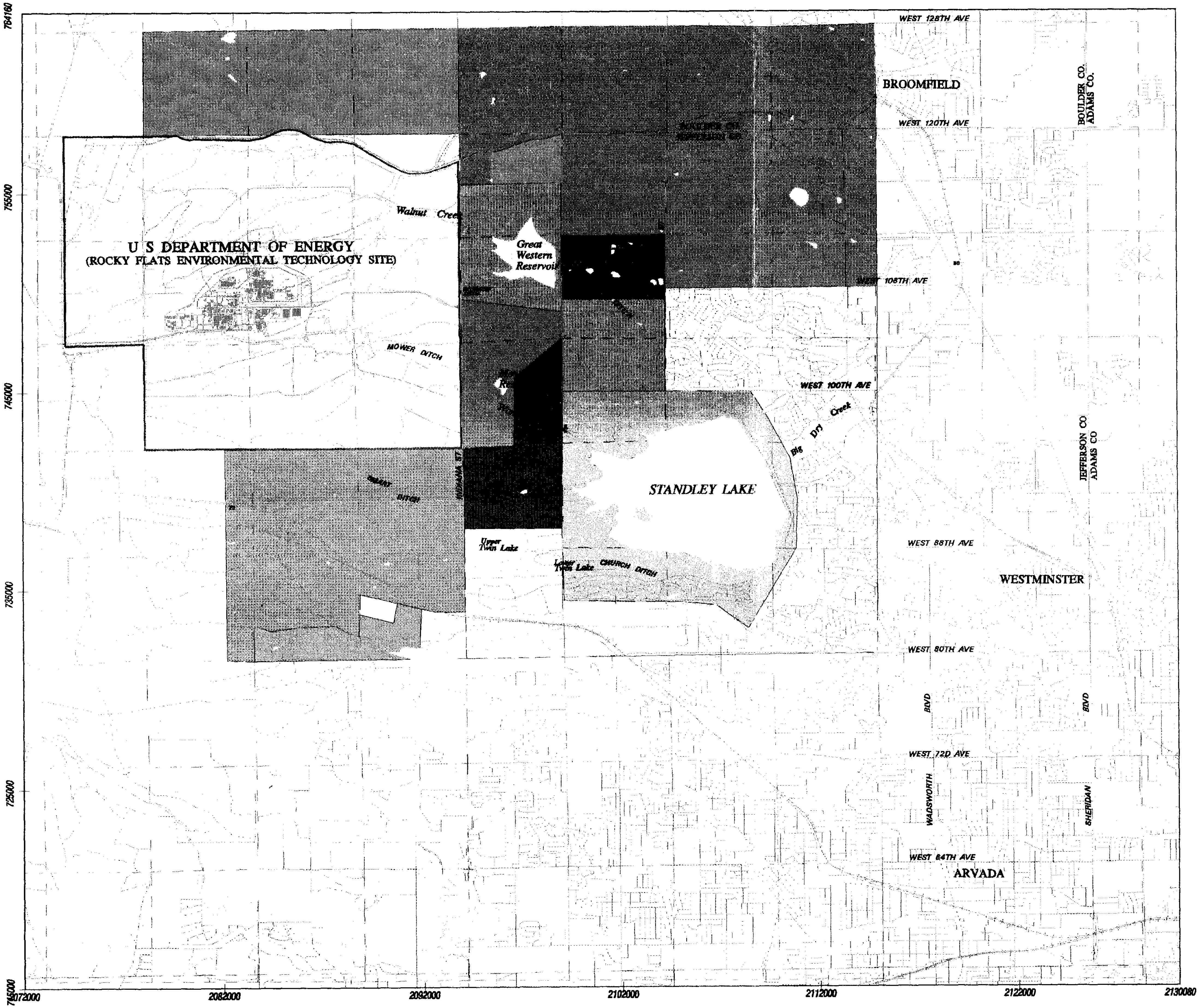

Figure 3-6

Potential Land Use
Operable Unit 3

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

MAP FILE NAME: TMFIG3-6.EPS
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September 13, 1995
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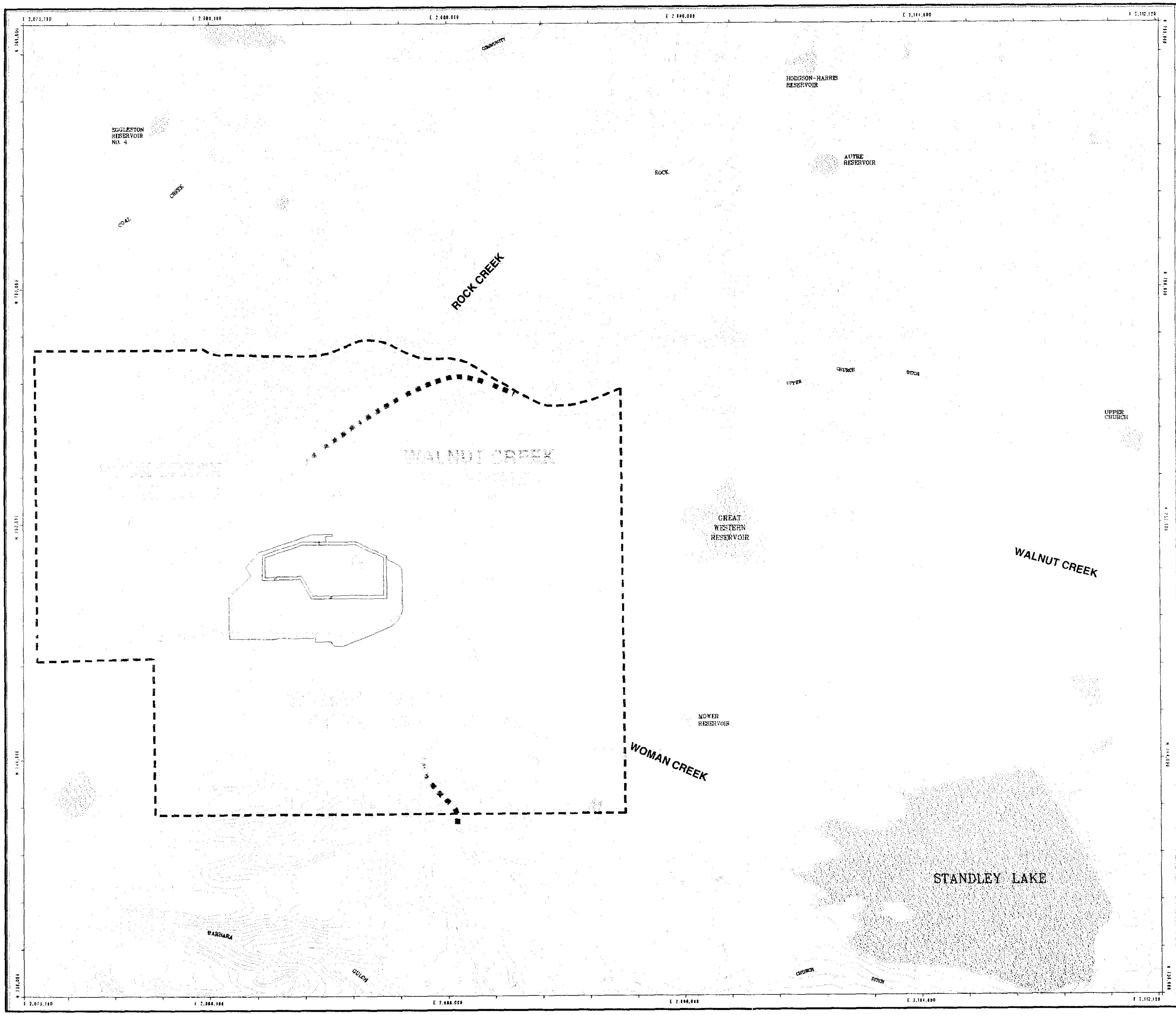


Figure 3-8

Drainage Basins in the Rocky Flats Environmental Technology Site Area

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

EXPLANATION

SITE LOCATION

SITE BOUNDARY

DRAINAGE BASIN BOUNDARY

TOPOGRAPHIC CONTOURS

STREAMS AND DRAINAGE

LAKES AND PONDS

N W E S

Scale = 1 : 36000

0 - Ft. 3000 6000

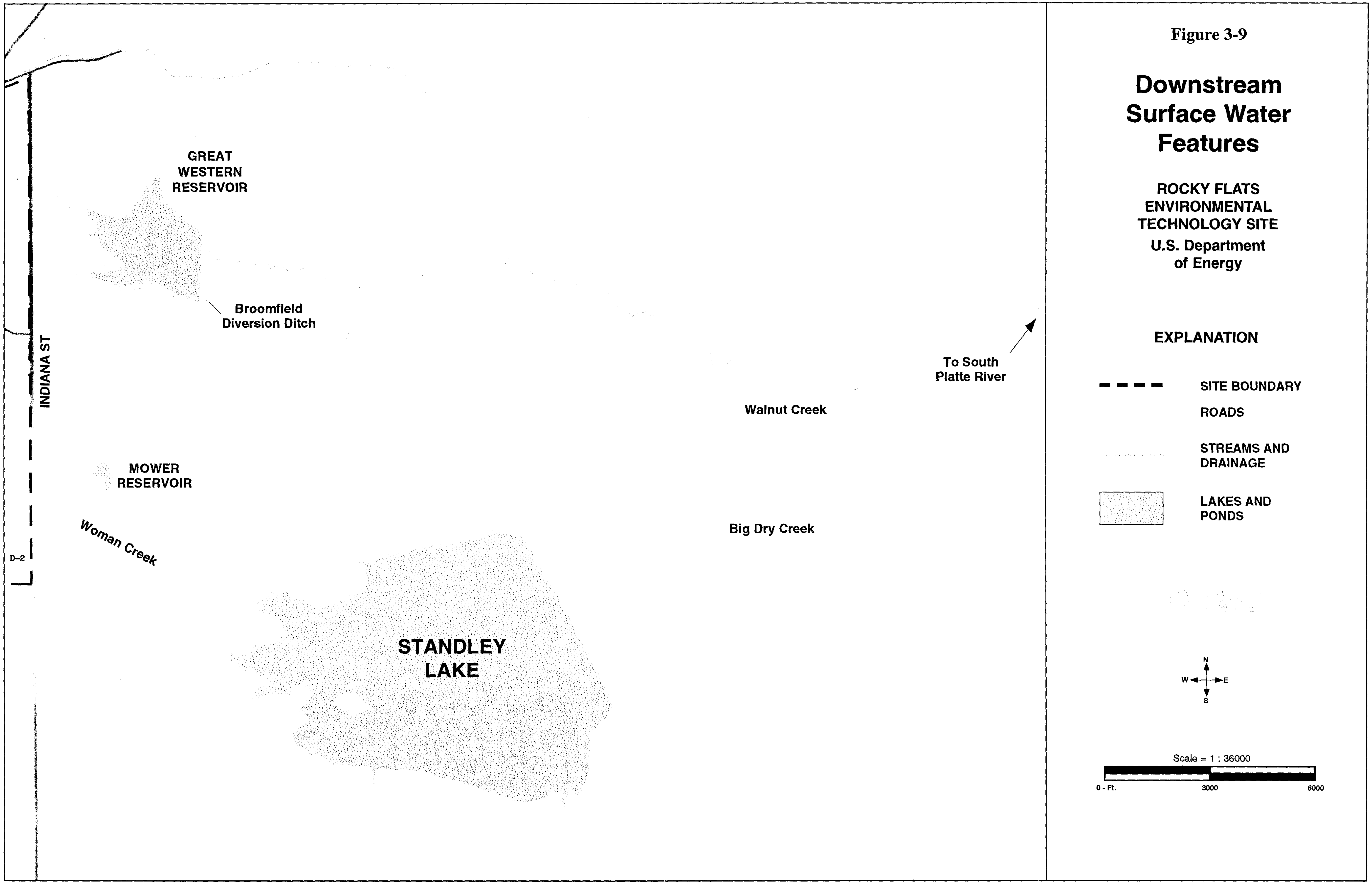


Figure 3-9

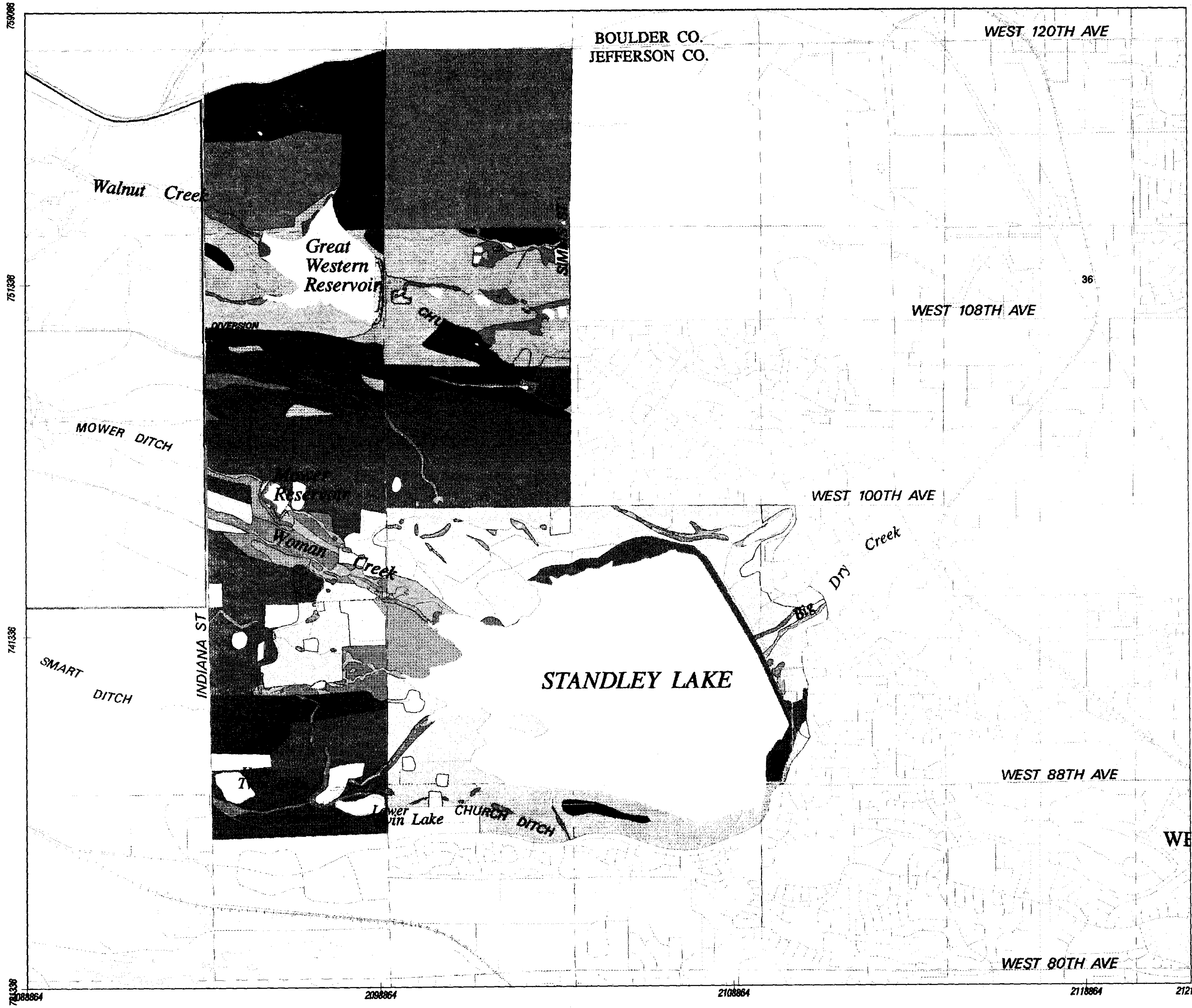
Downstream Surface Water Features

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Figure 3-14

Summary of Habitat Types
Operable Unit 3

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy



- aquatic & wetland habitat
- wet meadow/marsh ecotone
- short marsh
- tall marsh
- woodland habitat
- deciduous woodland
- bottomland shrubland
- grassland habitats
- short grass
- mixed grassland
- moist mixed grass
- xeric mixed grass
- disturbance categories
- annual grass/forb
- disturbed/barren lands
- cultivated lands
- grazed
- ungrazed
- cropland
- structure & str biotypes
- buildings/structures
- large lot residential
- industrial
- recreational
- open water

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats
U.S. Geological Survey

Scale 1:36000
1 inch = 3000 feet

0 1500 3000 6000
SCALE IN FEET

N

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

MAP FILE: TMFIG3-14.EPS
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DRAWN BY: tm3-14 ...reno/Campbell
APPROVED BY: J. Reynolds
September 13, 1995
Draft

TABLE 4-1

Summary of OU 3 Work Plan Activities and OU 3 Results

Data Item	Data Need from Work Plan	Field Activity (Refinements to Work Plan are Described in Section 2)	Data Use	Conceptual Model Pathway Addressed[1]	Summary of Results
S-1	Characterize vertical extent of soil contamination	Collected undisturbed soil samples from 11 trenches. Samples were collected at 10 depth intervals to a depth of 96 cm. Samples were collected at each soil horizon identified in the trenches. Samples were analyzed for plutonium, americium, uranium, general soil parameters, clay minerals, specified surface area, and bulk density.	Site characterization: evaluate depth of radionuclide migration; evaluate ratios of plutonium and americium. Risk assessment: assess pathway and transport potential. Ecological Risk Assessment	1, 2, 5	The soil trench data indicate that the highest activities of plutonium and americium are in the top 0 to 3 cm of soil. The highest activities of plutonium were detected in surface soils from trench TR03492 (1.593 pCi/g) and trench TR02792 (1.412 pCi/g) at a depth of 0 to 3 cm below ground surface (see Figure 2-1). The highest activities of americium were detected from 0 to 3 cm below ground surface in trenches TR02792 (0.2723 pCi/g), TR03492 (0.1441 pCi/g), and TR03692 (0.1276 pCi/g). Plutonium and americium activities decrease with depth to less than 0.10 pCi/g for plutonium and 0.01 pCi/g for americium at a depth of approximately 10 cm. The detected activities of plutonium and americium in soil below 10 cm are similar to the upper-bound background activities (mean values plus two standard deviations) for plutonium (0.04 pCi/g) and americium (0.09 pCi/g). The highest activities of uranium isotopes were observed in trench TR03692 (2.02 pCi/g for uranium-233/234, 0.36 pCi/g for uranium-235, and 2.15 pCi/g for uranium-238). Uranium activities are variable with depth below ground surface and appear to represent natural variability in subsurface soils. Plutonium, americium and uranium radionuclides do not appear to be migrating with depth in the soils.
S-2	Characterize lateral extent of soil contamination	Sixty-one, 10-acre soil plots were sampled in IHSS 199 for the OU 3 RFI/RI. The surface soil samples were collected using the CDPHE and RFP sample collection methods and were analyzed for plutonium, americium, and uranium. In addition, results of the 1991 Remedy Lands surface soil sampling investigation were used to provide additional information for characterizing the portion of IHSS 199 located adjacent to the RFETS eastern boundary. A total of 47 surface soil samples were collected (in 1991) from the tilled and untilled strips of land within the Remedy Lands area. These samples were analyzed for plutonium and americium (see Figure 2-1). Further discussion of the Remedy Lands soil investigation may be referenced in Section 4.3.1 of this report.	Site characterization. Risk assessment: assess pathway and potential exposure through ingestion. Ecological Risk Assessment.	1, 2, 3, 4, 6	Nineteen of the 61 RFI/RI soil plot samples contained plutonium and/or americium activities that exceed the upper-bound background values for plutonium (0.04 pCi/g) and americium (0.09 pCi/g). Plutonium activities were detected above 1pCi/g in only one of the RFI/RI 10-acre soil plots (2.95 pCi/g plutonium-239/240 was detected in the 10-acre plot sample PT14192, located immediately east of the Rocky Flats east entrance area - see Figure 2-1). The highest activities of plutonium-239/240 and americium-241detected in the 10-acre soil plot samples were 2.95 pCi/g and 0.52 pCi/g, respectively. The highest activities of uranium isotopes detected in the 10-acre soil plots were as follows: uranium-233/234: 2.140 pCi/g; uranium-235: 0.124 pCi/g; and uranium-238: 2.132 pCi/g. All of the 47 Remedy Lands surface soil samples (collected in 1991) contained plutonium and/or americium activities that exceed the upper-bound background values for plutonium and americium. Twenty-one of the 47 soil samples collected within the Remedy Lands area had plutonium activities greater than 1 pCi/g (and up to 6.468 pCi/g). The highest activities of plutonium-239/240 and americium-241 detected in the Remedy Lands surface soils were 6.468 pCi/g (at location U1A) and 0.52 pCi/g (at location PT14192), respectively (see Figure 4-4). Plutonium and americium were identified as Chemicals of Concern (COCs) in IHSS 199 surface soils. Plutonium and americium were evaluated as potential COCs in the Ecological Risk Assessment (ERA), but were determined not to be COCs in the terrestrial ecosystem. Uranium isotopes were not identified as COCs.
S-3	Delineate lateral extent of soil types and correlate with vegetation types	Soil types were identified at each 10-acre soil plot and vegetation types were classified at selected locations.	Ecological Risk Assessment.	6	This activity was conducted at selected areas (i.e., the trench locations). The study results were used in the ERA site characterization.
S-4	Characterize fate and transport of plutonium and americium	Soil samples were collected at each horizon identified in the soil trenches. Samples were analyzed for general soil physical parameters, clay minerals, specific surface area, total organic carbon (TOC), and bulk density.	Risk assessment: assess transport potential.	1, 2, 3, 4, 6	Trench soil profiles and the soil physical parameter measurements indicated plutonium and americium are not migrating with depth in soil. The highest levels of plutonium and americium were detected from the 0 to 3 cm depth interval.
SED-1, SED-2	Characterize potential contamination in drainage/ditches and reservoir sediments	1992 RFI/RI Sediment Data: surface sediment (grab) samples were collected from 30 creek/drainage locations and 97 surface/subsurface reservoir locations. Some locations were sampled more than once. Sediment core samples were also collected from each reservoir. Samples were analyzed for plutonium, americium, uranium, TAL metals, VOCs (Mower Reservoir only), tritium (Great Western Reservoir only), and cyanide. 1983/1984 Sediment Data: a total of 114 reservoir sediment samples were collected from Great Western Reservoir, Standley Lake and Mower Reservoir and analyzed for plutonium.	Site characterization. Risk assessment: assess transport media. Ecological Risk Assessment.	3, 7, 8, 10	The maximum plutonium activities detected in grab sediment samples were observed in grab samples collected from Great Western Reservoir (3.1, 3.2, and 3.3 pCi/g) during the 1983/1984 sampling event. All other sediment grab sample results were less than 1 pCi/g. Based on a comparison of OU 3 data to background stream sediment data, activities of plutonium and americium in OU 3 stream sediments are within background levels. The maximum activity for plutonium in creek sediments (0.55 pCi/g) was measured at location SED00192 near Great Western Reservoir (Figure 2-3). The maximum activity for americium in creek sediments (0.08 pCi/g) was found at location SED01992 near Standley Lake (Figure 2-4). The maximum activities for uranium isotopes slightly exceed the maximum background stream sediment values. Maximum plutonium levels in sediment (for both core and grab samples) was observed at a depth of 18 to 20 inches in a core sample collected from Great Western Reservoir (location SED09192 - 4.03 pCi/g). The core subsurface sediment sample results indicate that elevated plutonium activities are not variable with depth, but are encased within discrete depositional layers and are not migrating. Plutonium was identified as a COC in Great Western Reservoir sediments. Six VOCs were detected in sediment samples collected from Mower reservoir, but were not retained as potential COCs (see discussion presented in Section 4.5.1).
SED-3	Characterize potential plutonium, americium, and uranium entrapment to sediments exposed along shoreline	Thirty-four nearshore sediment locations were sampled (at Great Western reservoir, Standley Lake, and Mower Reservoir). At eight locations, vertical profile samples were also collected at 1-inch intervals to a depth of 6 inches. Samples were analyzed for plutonium, americium and uranium.	Site characterization. Risk assessment. Ecological Risk Assessment.	3, 7, 8, 10, 14	No plutonium activities in nearshore sediment samples exceeded 1 pCi/g. The maximum detection of plutonium in nearshore sediments (0.55 pCi/g) was detected near Great Western Reservoir. For most analytes, nearshore sample results were less than reservoir sample results, particularly in Standley Lake. Plutonium was identified as a COC in Great Western Reservoir sediments. Plutonium was identified as a PCOC in sediments for the ERA but was determined not to be a COC in the aquatic or terrestrial ecosystems.
SW-1, SW-2	Characterize potential plutonium, americium, uranium, and metals contamination in surface water reservoirs and creeks/drainages. Characterize potential VOCs in Mower Reservoir only.	A total of 53 surface water samples were collected from 33 locations at Great Western Reservoir, Standley Lake, and Mower Reservoir. Some samples were collected with sediment and biota samples. Six creek/drainage locations were sampled. Surface water sampling in the creeks/drainages was limited due to intermittent flows.	Site characterization. Risk assessment; assess pathway and potential exposure through ingestion of surface water. Ecological Risk Assessment.	4, 9, 12	Radionuclides and metals were detected within background and benchmark levels for each of the three reservoirs. No VOCs were detected in surface water samples collected from Mower Reservoir. No COCs were identified for surface water. No surface water PCOCs were identified for evaluation in the ERA.
GW-1	Characterize hydrogeology near IHSSs and groundwater/surface water interactions and contamination	Two monitoring wells were installed for OU 3; one downstream of Great Western Reservoir and one downstream of Standley Lake. Both wells were sampled 8 times over a one-year period. Groundwater samples were analyzed for plutonium, americium, uranium, TAL metals, cations/anions, and nitrates.	Site characterization. Risk assessment; assess pathway and potential exposure through ingestion of groundwater.	5, 10, 12	No COCs were identified for groundwater. Potassium and strontium were slightly elevated above background in groundwater, but were eliminated as COCs through the COC identification process (see discussion in Section 4.6.2). Radionuclide contamination observed in reservoir sediments does not appear to be migrating to groundwater.

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TABLE 4-1 (Continued)

Summary of OU 3 Work Plan Activities and OU 3 Results

A-1	Characterize particulates in air	Collected discrete air samples from exposed reservoir sediments and vegetated soil areas using a wind tunnel and analyzed air samples for plutonium, americium, and uranium. High-volume air samplers were installed in the vicinity of Standley Lake.	Site characterization: Risk assessment; assess pathway, transport media, and potential exposure through ingestion.	1, 7, 14	The results of the wind tunnel study indicate erosion potential is low. All surfaces (except for one highly disturbed shoreline site) exhibited erosion potential values less than predicted. Natural weathering (e.g., vegetative growth cycles and freezing/thawing) creates the equivalent of one moderate disturbance per year. Animals frequently moving over the surface cause the equivalent of additional annual disturbances. Observed PM-10/Total Particulate (TP) ratios were higher for exposed shoreline surfaces than for terrestrial (vegetated) surfaces. With an increase in disturbance level, the increase in TP emissions was greater than that of PM-10 (consequently, the ratio of PM-10/TP decreased). The highest threshold velocities (velocity at which wind erosion occurs) were observed on undisturbed vegetated terrestrial sites. All undisturbed terrestrial sites exhibited threshold velocities greater than 80 mph measured at 10 m. The lowest threshold values were observed at the highly disturbed shoreline sites, especially at the Walnut Creek inlet to Great Western Reservoir. The wind tunnel study results were used to support risk estimates from inhalation exposure. Data from the ultra high-volume air samplers are not available; these data will be incorporated in the final RFI/RI report.
B-2	Characterize animal species and populations	Thirteen small mammal grid trappings; 10 quantitative and 8 qualitative bird surveys, and 12 qualitative herpetological surveys were performed.	Site characterization: Comparative ecology:	6, 11	The common small mammals deer mice and micratines were observed at low densities. Birds and reptiles were observed in all habitats at moderate densities. Results of the ERA plutonium and americium PCOC evaluations for the terrestrial ecosystem indicated no effect to small mammals residing in OU 3.
B-3	Characterize wetlands/riparian zones	Five qualitative surveys of wetlands and riparian zones were performed.	Site characterization: Comparative ecology:	6, 11	Wetlands are small and occur below dams and reservoirs. Riparian zones are narrow bands along lower drainages that are managed for water conveyance.
B-4	Assess bioaccumulation in vegetation	Sixty-five tissue samples were collected from above-ground plant biomass at 13 sites and analyzed for plutonium, americium, and uranium.	Toxicity assessment: Exposure pathways:	6, 11	Contaminant concentrations were low in vegetation with about 20 percent defects and a soil to tissue concentration ratio of 0.05. Results of the ERA plutonium and americium PCOC evaluations for the terrestrial ecosystem indicated no effect to the OU 3 vegetation.
B-5	Assess bioaccumulation and concentration in wetland vegetation	As stated in TM No. 1, wetland vegetation was not sampled due to disturbance, heterogeneity, water management, and irrigation currently impacting the wetlands.	Toxicity assessment: Exposure pathways:	6, 11	This study was not conducted.
B-6	Assess bioaccumulation in small mammals	Forty-one tissue samples were collected at 13 sites and analyzed for plutonium, americium, and uranium.	Toxicity assessment: Exposure pathways:	6, 11	Contaminant activities detected in small mammal tissue was less than .005 pCi/g. An evaluation of the observed tissue concentrations was conducted for the terrestrial ERA and it was determined that there is no effect (of PCOC uptake) to the OU 3 small mammal receptors.
AQ-1, AQ-4	Characterize benthic macroinvertebrate communities in creeks and reservoirs	Benthic macroinvertebrate sampling was conducted in Woman Creek, Walnut Creek, Big Dry Creek, Great Western Reservoir, and Standley Lake. Samples were collected at one station per creek and at three to four locations per reservoir. Species identification and enumeration was performed. Bioaccumulation in tissue was not performed because adequate tissue mass could not be obtained for analytical requirements.	Site characterization: Ecological Risk Assessment: exposure pathways, ecological endpoints and comparative ecology.	13	Due to the presence of multiple variables within each environment which can affect species occurrence and distribution (i.e., depth, flow, bottom substrate composition and water quality), the results were used to qualitatively interpret ecological effects. Results of the aquatic ecosystem ERA indicate that the populations residing within all OU 3 IHSSs are typical of these types of ecosystems and that no effects were observed. Similarly, no effect was determined for these receptors by conducting an exposure point activity and dose level comparison to benchmark NOAEL levels. Resulting hazard quotients fell below a level of 1 (indicating no effect) by at least one order of magnitude.
AQ-2, AQ-5	Characterize periphyton in creeks and reservoir areas	Quantitative periphyton sampling was conducted at Great Western Reservoir, Mower Reservoir, and Standley Lake using artificial substrate samplers. Biomass, algae density, and taxonomic identification was performed. No periphyton sampling was performed in the creeks because there was no flow in the creeks.	Site characterization: Ecological Risk Assessment: comparative ecology	13	The results were used to qualitatively determine periphyton species occurrence. Risk was not quantified since there were no surface water PCOCs identified.
AQ-3, AQ-6	Characterize fish communities in creeks and reservoirs	Fish sampling was conducted in Woman Creek, Walnut Creek, and Big Dry Creek using electroshocking techniques; fish were collected from Great Western Reservoir, Mower Reservoir, and Standley Lake using gill nets and boat electroshocking techniques. Species identification, enumeration, and observation of incidence of disease was performed.	Site characterization: Ecological Risk Assessment: exposure pathways, ecological endpoints, and comparative ecology.	13	Since fish populations are supplemented, by stocking practices within Mower Reservoir and Standley Reservoir, (which would affect species composition within Woman Creek and Big Dry Creek) the results were used to qualitatively determine species occurrence. Similarly, species occurrence within Great Western Reservoir and Walnut Creek is also subject to resource use effects, therefore, the information obtained was used for qualitative determination of receptor identification. Results of the ERA evaluation of risk to fish and fish eggs indicate no effect to these receptors. Risk was quantified by a comparison of observed maximum exposure point activity levels and dose to benchmark NOAEL levels. Resulting hazard quotients fell below a level of 1 (indicating no effect) by at least one order of magnitude for each IHSS.

Notes: 1. Conceptual Model Pathway designations as presented in Figure 5-1

pCi/g = picocuries per gram
CDPHE = Colorado Department of Public Health and Environment
COC = Chemical of Concern
ERA = Ecological Risk Assessment
HHRA = Human Health Risk Assessment
NOAEL = No Observed Adverse Effect Level
PCOC = Potential Chemical of Concern
TAL = Target Analyte List
TP = Total Particulates

DRAFT

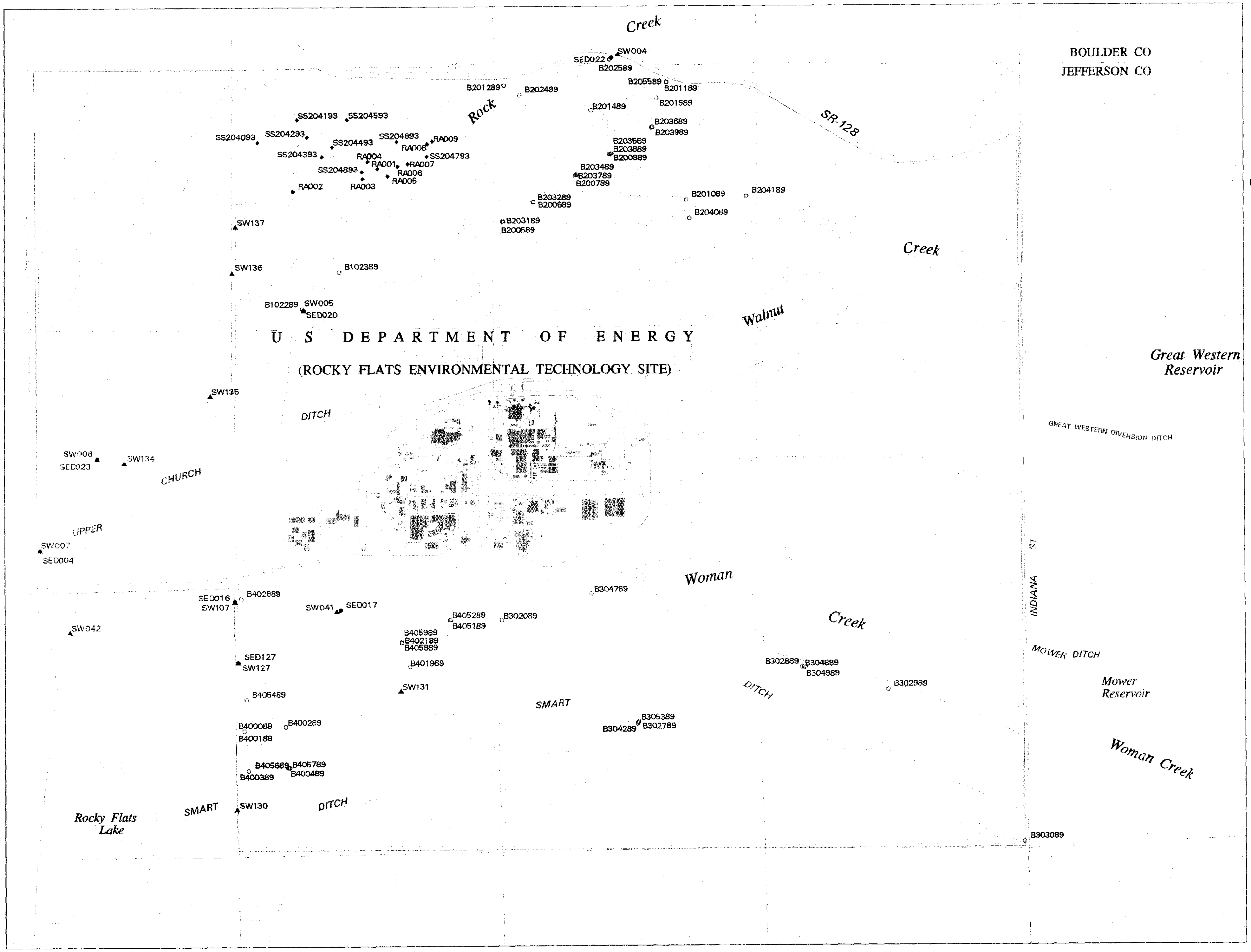

Figure 4-2
Background Sample Locations Operable Unit 3

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

- ● Background sediment sample point
- ▲ Background surface water sample
- ○ Background ground water sample
- ◆ Rock Creek background soil sample

Note: Sample location codes shown on this map correspond to their identification in the Rocky Flats Environmental Database System (RFEDS).

DRAFT

Mapping Sources:
Jefferson County Mapping Dept
EG&G Rocky Flats
U.S. Geological Survey

N

Scale 1 : 24000
1 inch = 2000 ft

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SCALE IN FEET

Polyconic projection. 1927 North American datum. Colorado central zone state plane coordinate system.

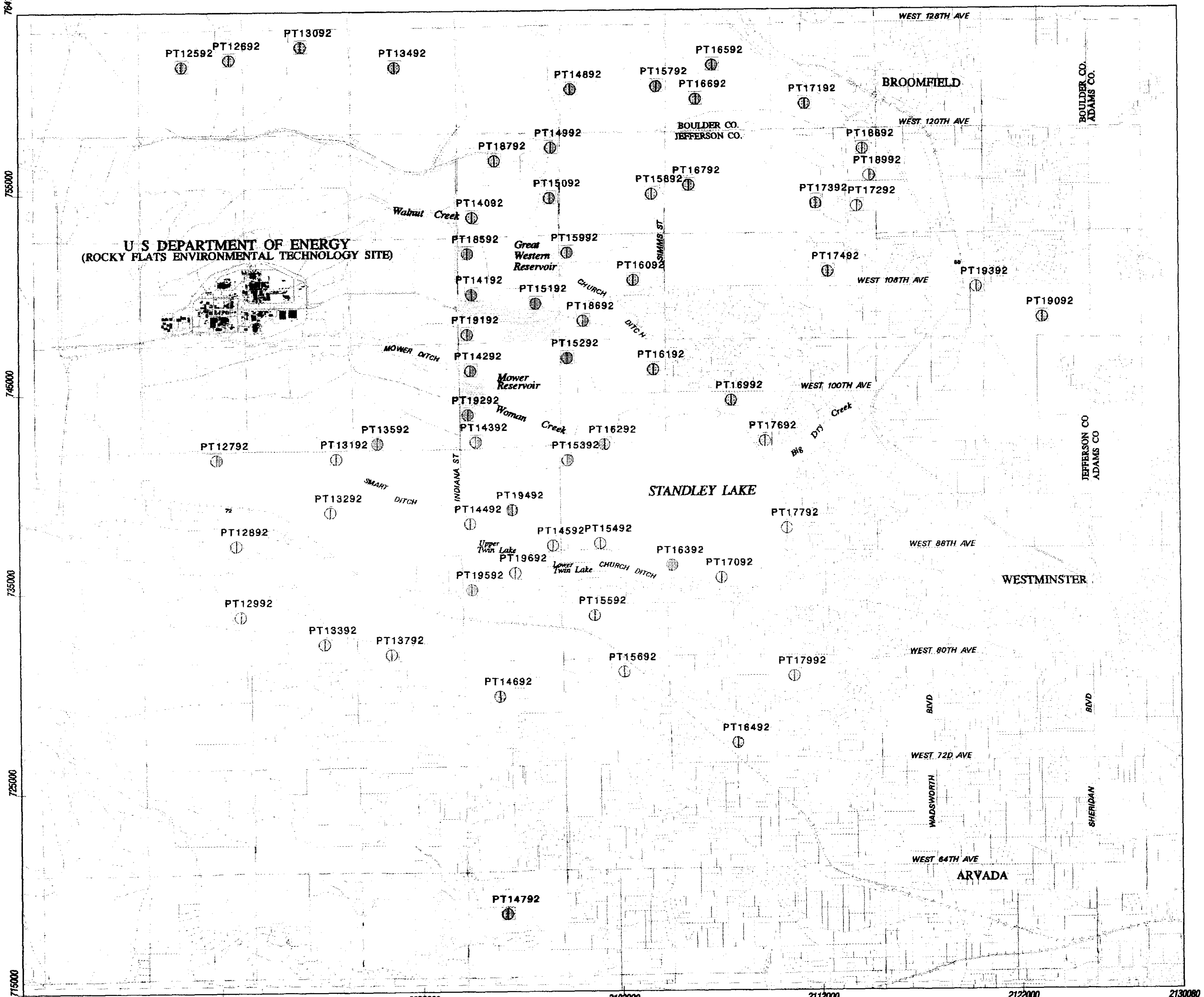

Figure 4-3
RFI/RI Surface Soil Plots
Surface Soils / Radionuclides
Ratios of 241Am and 239/240Pu to Background Levels
Operable Unit 3
IHSS 199 - Surface Soil Sampling Area

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Key to Symbols
241Am 239/240Pu

DRAFT

Key to Symbol Colors
Background Ratio (Comparison to background)
- < 1 (Does not exceed background)
- > 1 (Exceeds background)
- Rejected Data

RFI/RI soil sample plot

untilled
tilled
Remedy Lands Area

The symbols show the ratios of each radionuclide (241Am and 239/240Pu) to the upper-bound background values (mean + 2 std dev).

Ratios are calculated using average values of CDH and RFP soil-sampling methods for RFI/RI plots, and maximum values for Remedy Lands. The circular symbols represent data collected within the soil sample plots; however, the placement of the symbol does not indicate the exact location of where a sample was taken.

The reference levels (in pCi/g) used to calculate ratios are as follows:

REFERENCE LEVEL	241 Am	239/240 Pu
MEAN+2STD	0.04	0.09

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats, Inc.
U.S. Geological Survey

N

Scale 1:63360
1 inch = 1 mile
0 0.5 1 2
MILES

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

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DRAWN BY:	D. Moreno
APPROVED BY:	
	September 22, 1995
	Draft

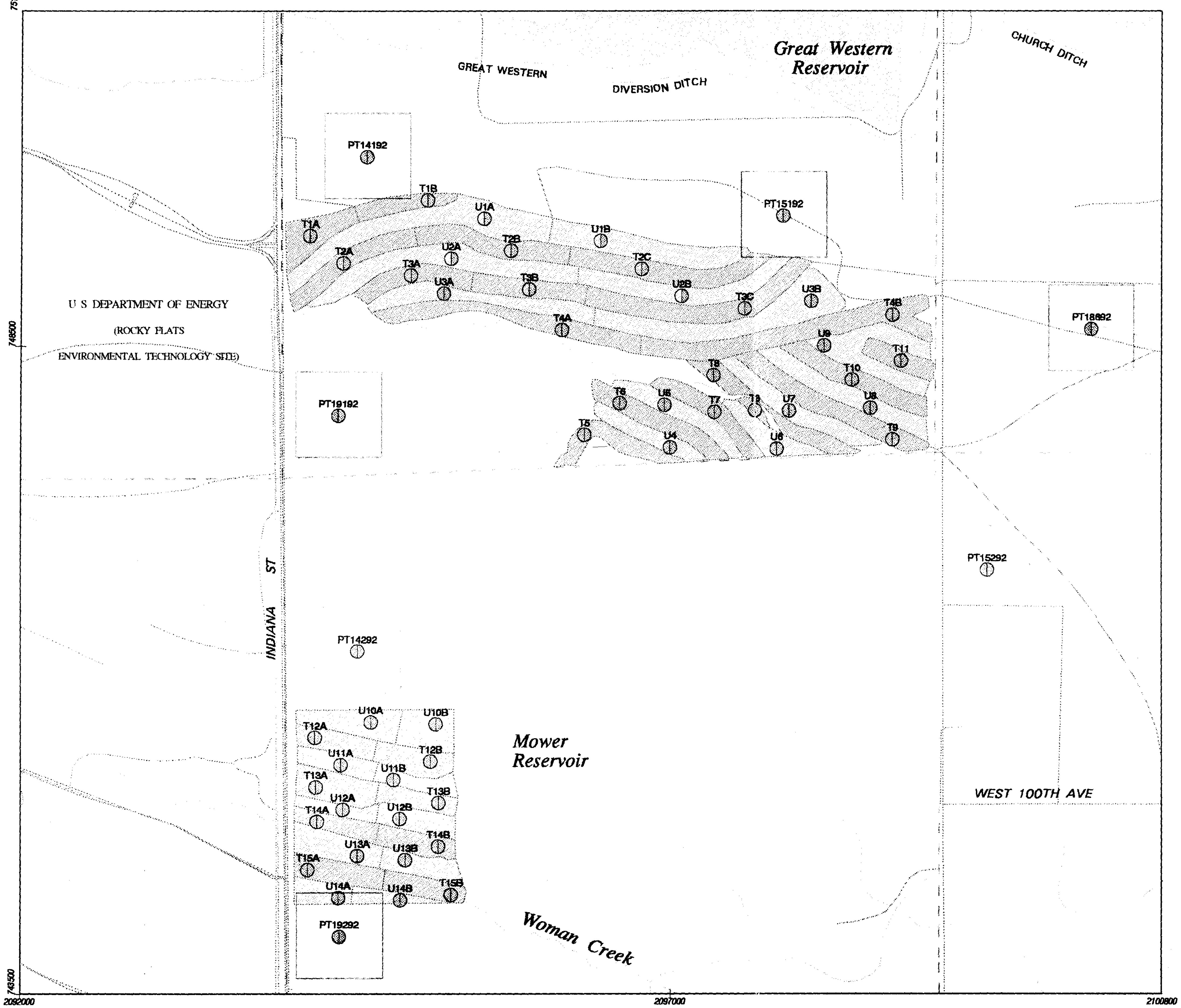

Figure 4-4
Remedy Lands
Surface Soils / Radionuclides

Ratios of 241Am and 239/240Pu to Background Levels
Operable Unit 3
IHSS 199 - Surface Soil Sampling Area

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Key to Symbols
241Am 239/240Pu

DRAFT

Key to Symbol Colors
Background Ratio (Comparison to background)
- < 1 (Does not exceed background)
- > 1 (Exceeds background)
- Rejected Data

RFI/RI soil sample plot

untilled
tilled
Remedy Lands Area

The symbols show the ratios of each radionuclide (241Am and 239/240Pu) to the upper-bound background values (mean + 2 std dev).

Ratios are calculated using average values of CDH and RFP soil-sampling methods for RFI/RI plots, and maximum values for Remedy Lands. The circular symbols represent data collected within the soil sample plots; however, the placement of the symbol does not indicate the exact location of where a sample was taken. The reference levels (in pCi/g) used to calculate ratios are as follows:

REFERENCE LEVEL	241 Am	239/240 Pu
MEAN+2 STD DEV	0.04	0.09

Mapping Sources:
Jefferson County Mapping Dept.
EG&G Rocky Flats, Inc.
U.S. Geological Survey

N

Scale 1:9600
1 in = 800 ft
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SCALE IN FEET

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

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DRAWN BY: D. Moreno
APPROVED BY:
October 04, 1995
Draft RI Report
Fig 4-4

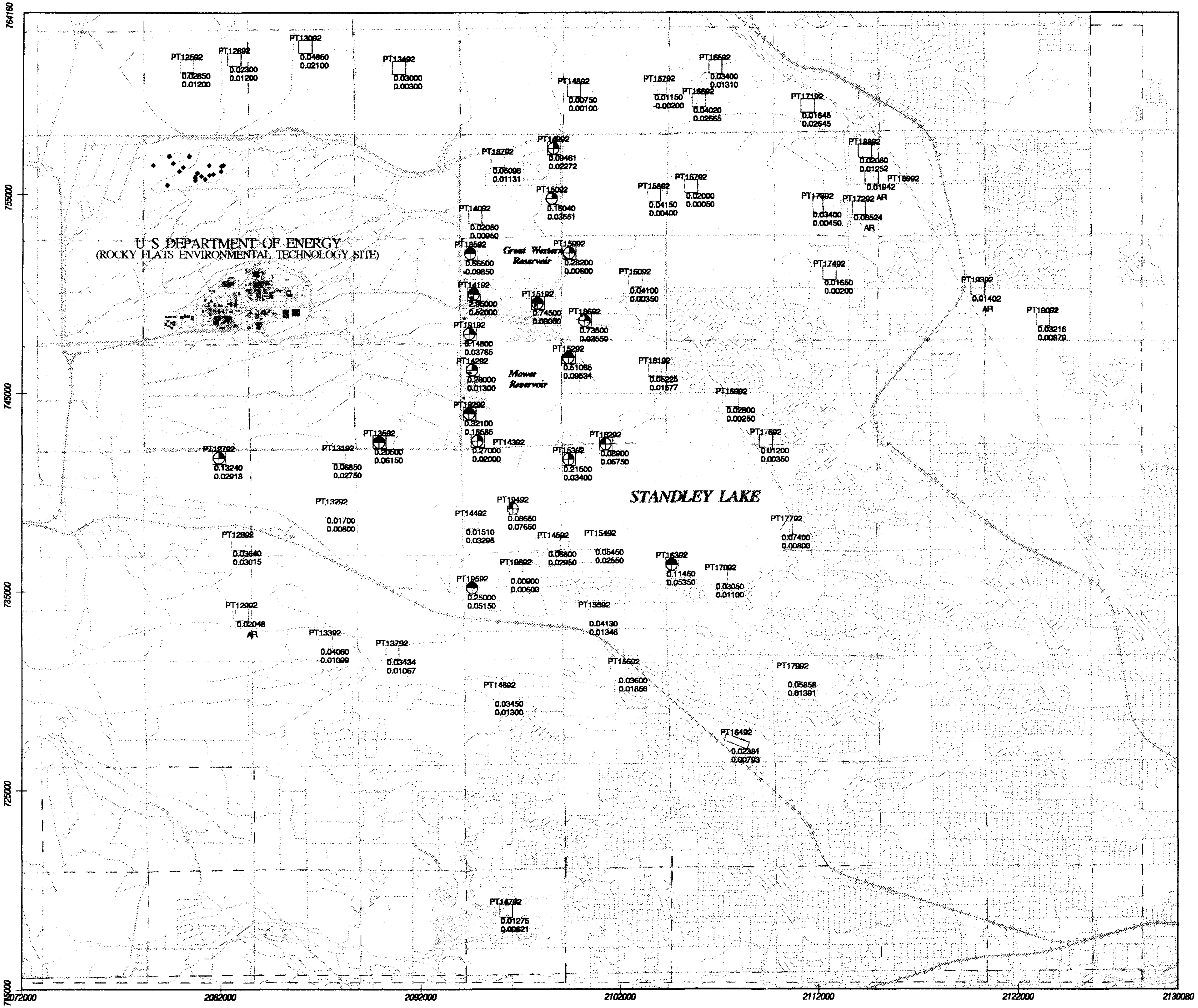

Figure 4-5A
Am-241 and Pu-239/240 Results for Soil
Surface Soils
Radionuclides - Average* Values
OPERABLE UNIT 3
IHSS 199 - Surface Soil Sampling Area

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

*RFI/RI soil plot values are the averages of CDH and RFP soil sampling methods. Units are in pCi/g.

Key to Symbols

Am 241 | Pu 239/240

m+2sd PRG — Exceedance

Results: Pu-239/240 Am-241 — AR = analysis rejected

RFI/RI soil trench

RFI/RI soil sample plot

untilled / tilled — Remedy Lands Area

Area of Concern

• Rock Creek background sample

Note: the symbols represent soil plots and indicate where values of Am-241 and Pu-239/240 exceed each of two reference levels: background (mean + 2 std dev of the Rock Creek soil samples) and PRG.

The levels used to derive exceedances are as follows:
Am-241 background: 0.04
Am-241 PRG: 2.37
Pu-239/240 backgound: 0.09
Pu-239/240 PRG: 3.43

DRAFT

Mapping Sources:
Jefferson County Mapping Dept
EG&G Rocky Flats
U.S. Geological Survey
CH2M HILL, Inc.

Scale 1:63360
1 in = 1 mi

0 0.5 1 2
MILES

N

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

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DRAWN BY: M. Campbell
APPROVED BY:
October 04, 1995

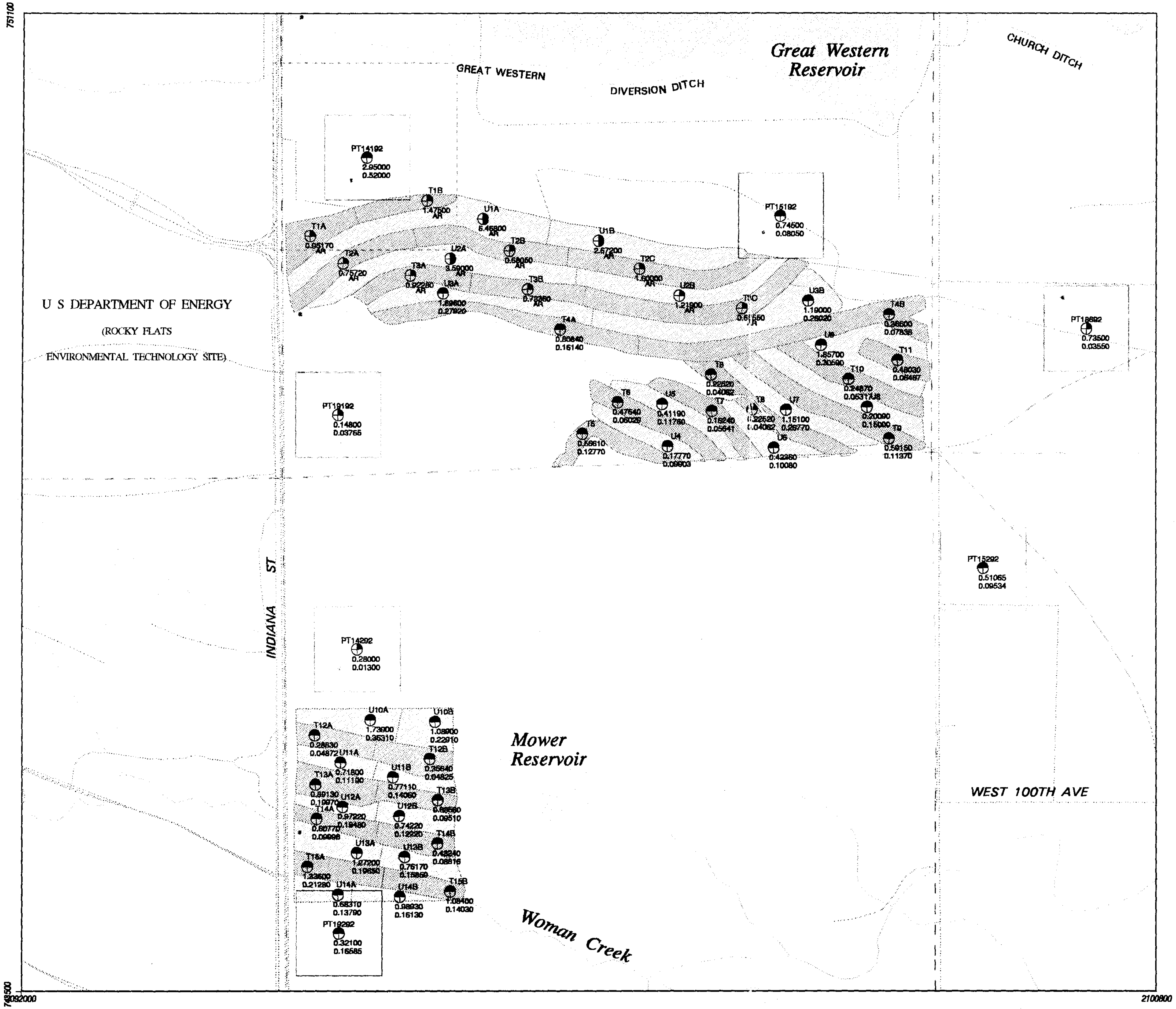

Figure 4-5B

Am-241 and Pu-239/240 Results for Soil

Surface Soils
Radionuclides - Maximum* Values
OPERABLE UNIT 3
IHSS 199 - Surface Soil Sampling Area

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

*RFI/RI soil plot values are the maximum of CDH and RFP soil sampling methods. Units are in pCi/g.

Key to Symbols

Am 241 | Pu 239/240

m+2sd / PRG — Exceedance

Results: Pu-239/240 / Am-241 — AR = analysis rejected

RFI/RI soil trench

RFI/RI soil sample plot

untilled / tilled — Remedy Lands Area

Area of Concern

Note: the symbols represent soil plots and indicate where values of Am-241 and Pu-239/240 exceed each of two reference levels: background (mean + 2 std dev of the Rock Creek soil samples) and PRG.

The levels used to derive exceedances are as follows:
Am-241 background: 0.04
Am-241 PRG: 2.37
Pu-239/240 backgound: 0.09
Pu-239/240 PRG: 3.43

DRAFT

Mapping Sources:
Jefferson County Mapping Dept
EG&G Rocky Flats
U.S. Geological Survey
CH2M HILL, Inc.

N

Scale 1:9600
1 in = 800 ft

0 250 500 1000
SCALE IN FEET

Polyconic projection. 1927 North American datum.
Colorado central zone state plane coordinate system.

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DRAWN BY: M. Campbell
APPROVED BY:

October 03, 1995

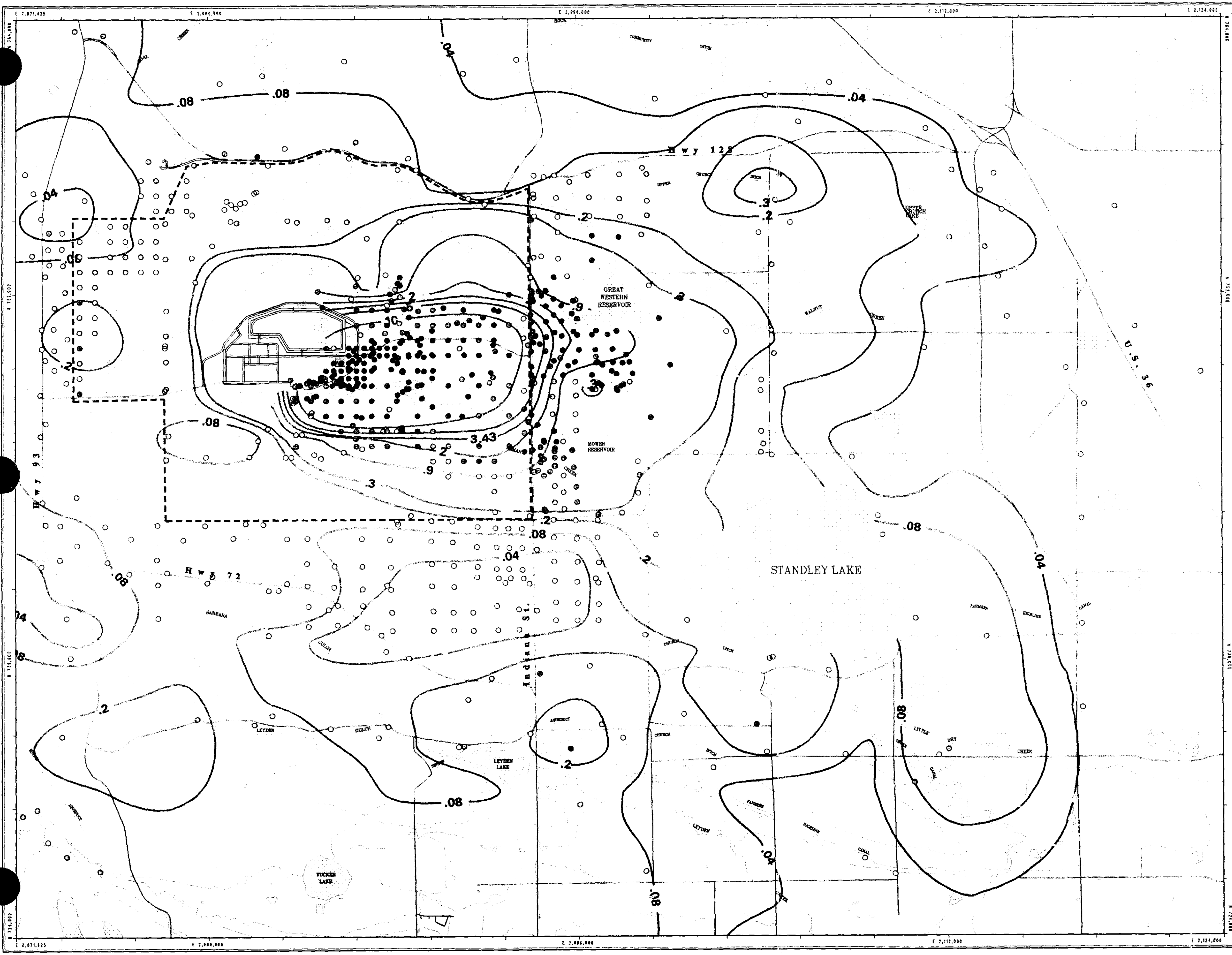

Figure 4-6A
Pu 239+240 (pci/g) Isoplot with Exhaustive Surface Soil Sampling Locations
(E-Type Estimate)

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Concentration Levels (pci/g)

- < 0.08
- 0.08 - 0.29
- 0.30 - 0.89
- 0.90 - 1.99
- 2.00 - 4.99
- 5.00 - 9.99
- > 10.00

Standard Features

- Isoplot Lines
- 903 Pad
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats boundary
- Major Roads
- Secondary Roads
- RFETS Roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr., EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)

The contours for this map were created in Dynamic Graphics using a Kriged data file from M. Iggy Litaor, EG&G Geosciences - Jan. 1995.

Scale = 1 : 50400
1 inch represents 4200 feet

1900 0 3800 7600 ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

MAP ID: pu239

October 18, 1995

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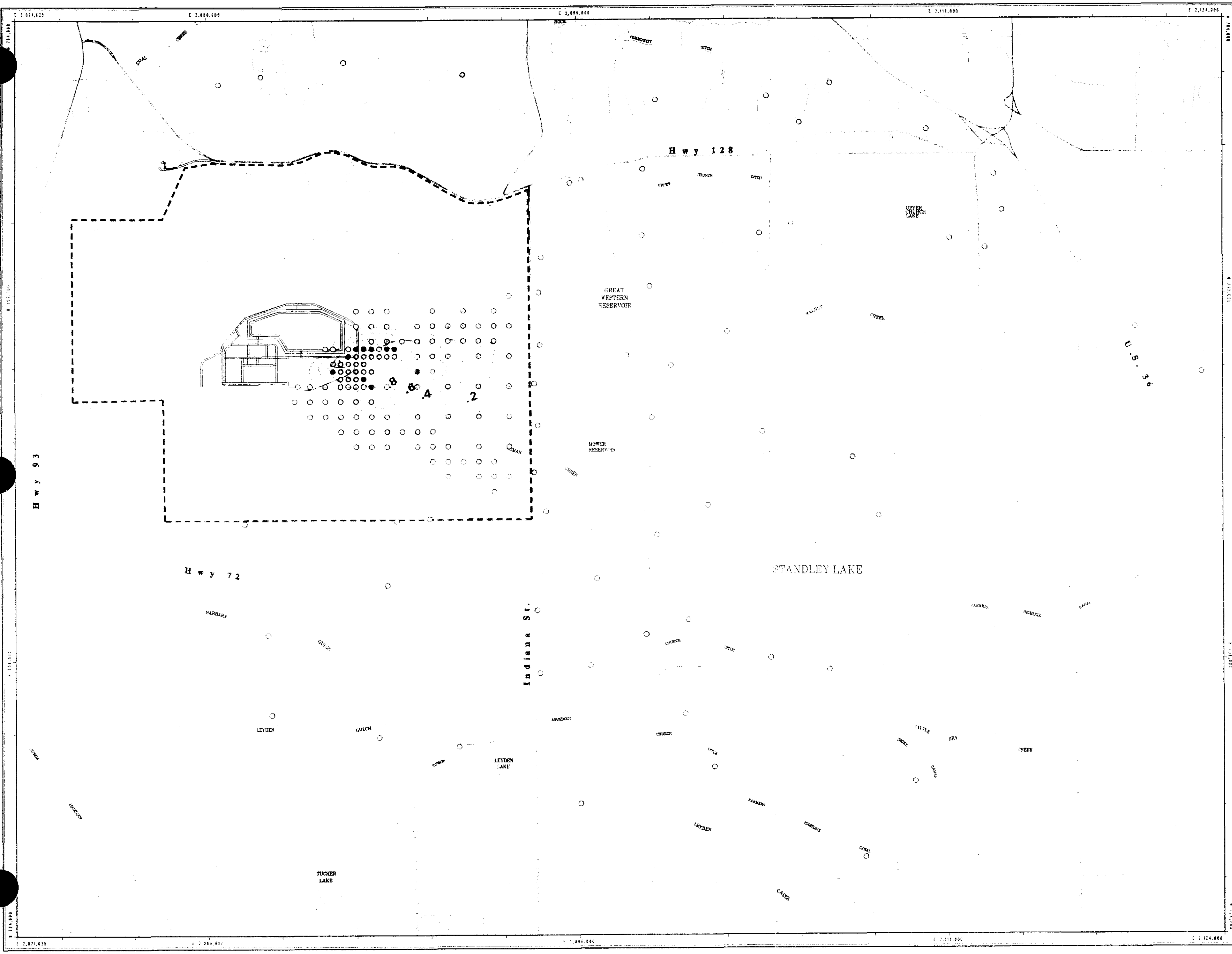


Figure 4-7B

Am 241 Probability > 2.37 pci/g
Isoplot with
Surface Soil Sampling Locations
(E-Type Estimate)

ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Concentration Levels (pci/g)

- < 0.08
- 0.08 - 0.29
- 0.30 - 0.89
- 0.90 - 1.99
- 2.00 - 4.99
- 5.00 - 9.99
- > 10.00

Standard Features

- Isoplot Lines
- 903 Pad
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats boundary
- Major Roads
- Secondary Roads
- RFETS Roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr.
EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)

The contours for this map were created in Dynamic Graphics using a Kriged data file from M. Iggy Litaor, EG&G Geosciences - Jan. 1995.

N

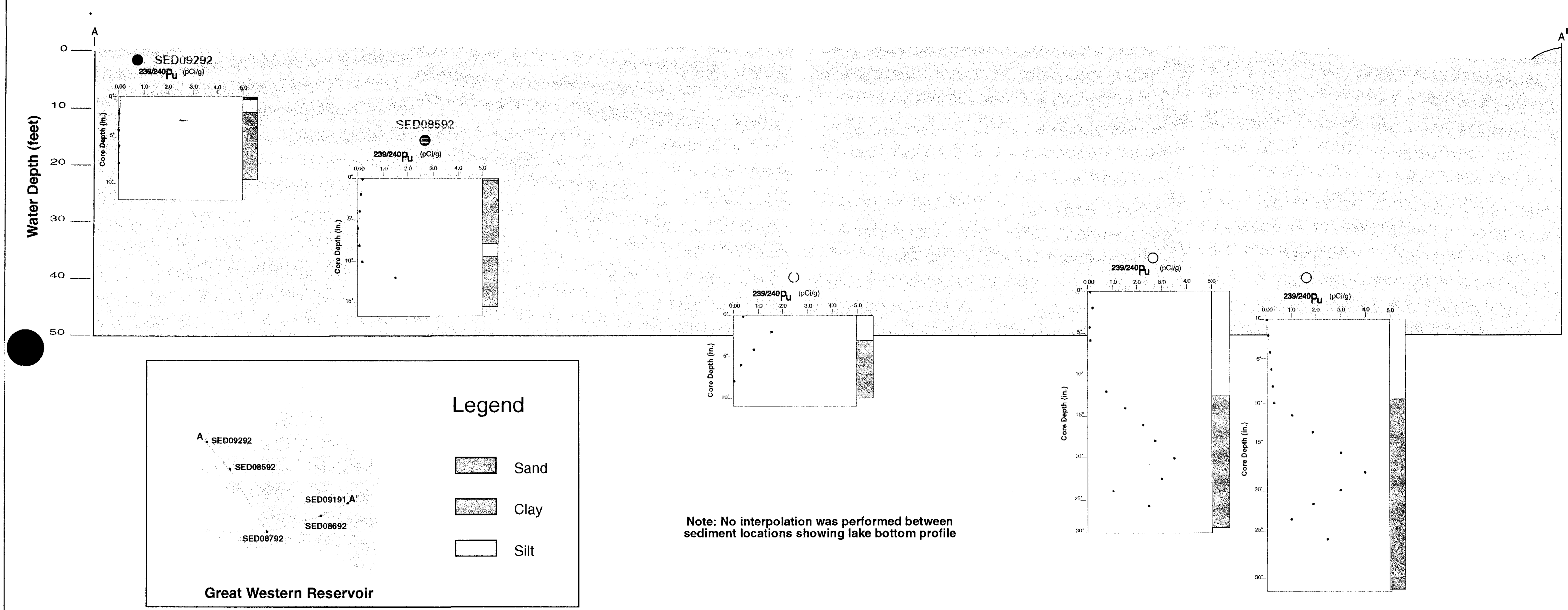
Scale = 1 : 50400
1 inch represents 4200 feet

1900 0 2800 7800ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

MAP ID: am241-p237

October 17, 1995



Note: No interpolation was performed between sediment locations showing lake bottom profile

Figure 4-9

Pu DEPTH PROFILES FOR GREAT WESTERN RESERVOIR

Operable Unit 3

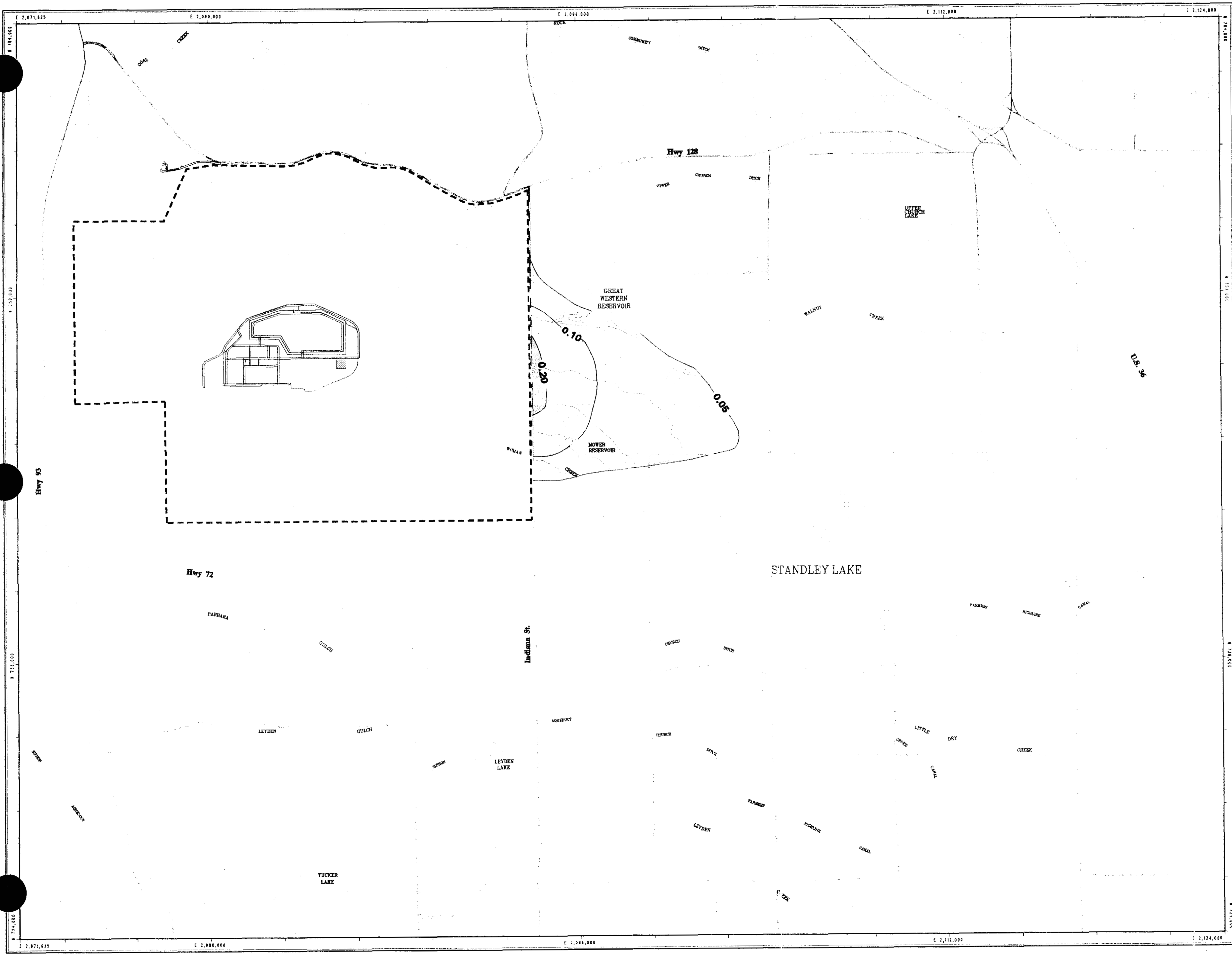


Figure 5-2

Increased Cancer Incedence per One Million People from 1990 Data Set
Extra Disturbed Inputs

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Incedence Levels (per 1 million)

- 0.05 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- > 0.50

Standard Features

- Incedence Contour
- 903 Pad
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats boundary
- Major Roads
- Secondary Roads
- RFETS Roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr., EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)

The contours created for this map were generated from an Air Modeling grid file using the Dynamic Graphics software system. (July, 1995)

Scale = 1 : 50400
1 inch represents 4200 feet

1900 0 3800 7600ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

MAP ID: Inced90

October 16, 1995

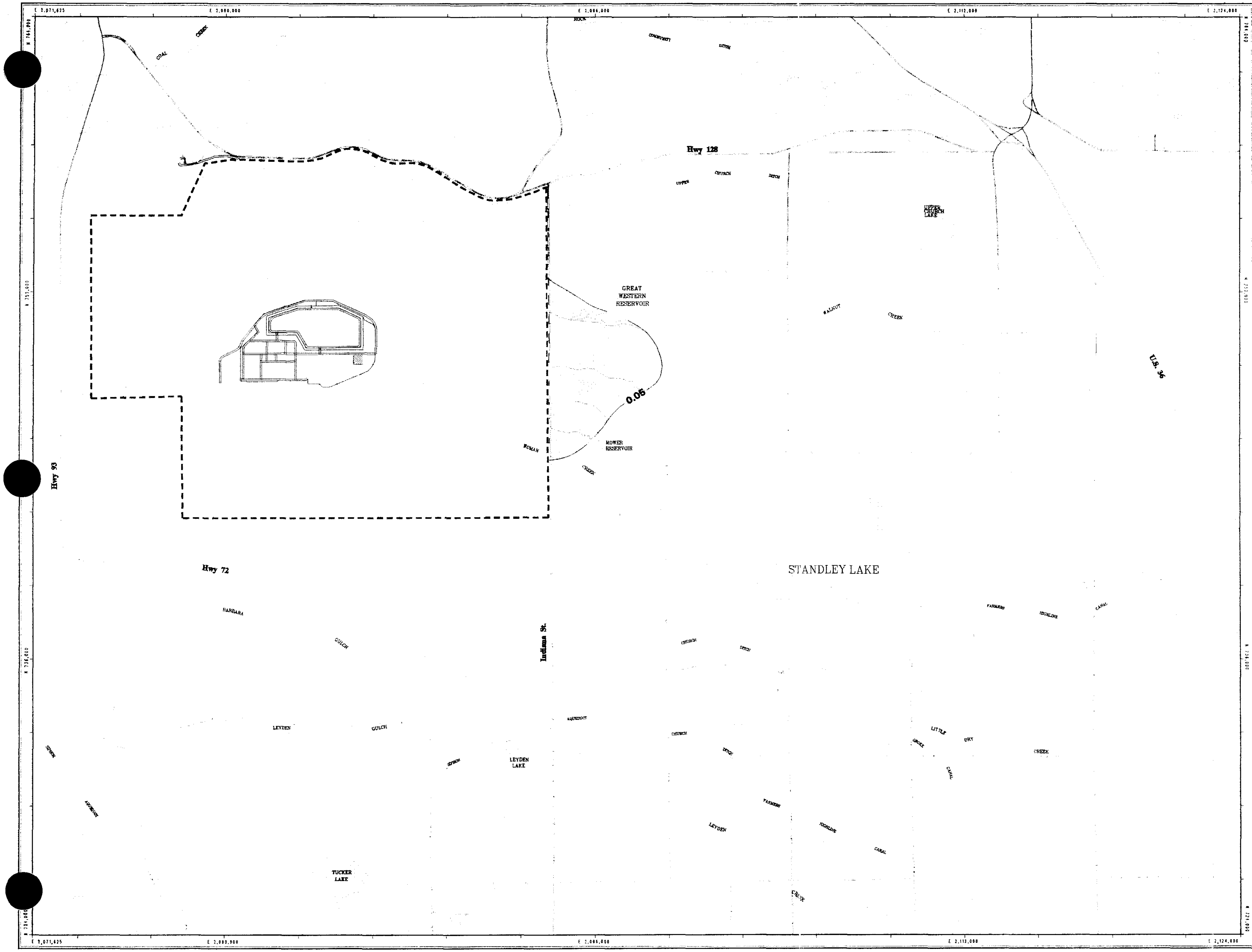


Figure 5-3

Increased Cancer Incedence per One Million People from 1991 Data Set

Extra Disturbed Inputs

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Incedence Levels (per 1 million)

- 0.05 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- > 0.50

Standard Features

- Incedence Contour
- 903 Pad
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats boundary
- Major Roads
- Secondary Roads
- RFETS Roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr., EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)

The contours created for this map were generated from an Air Modeling grid file using the Dynamic Graphics software system. (July, 1995)

Scale = 1 : 50400
1 inch represents 4200 feet

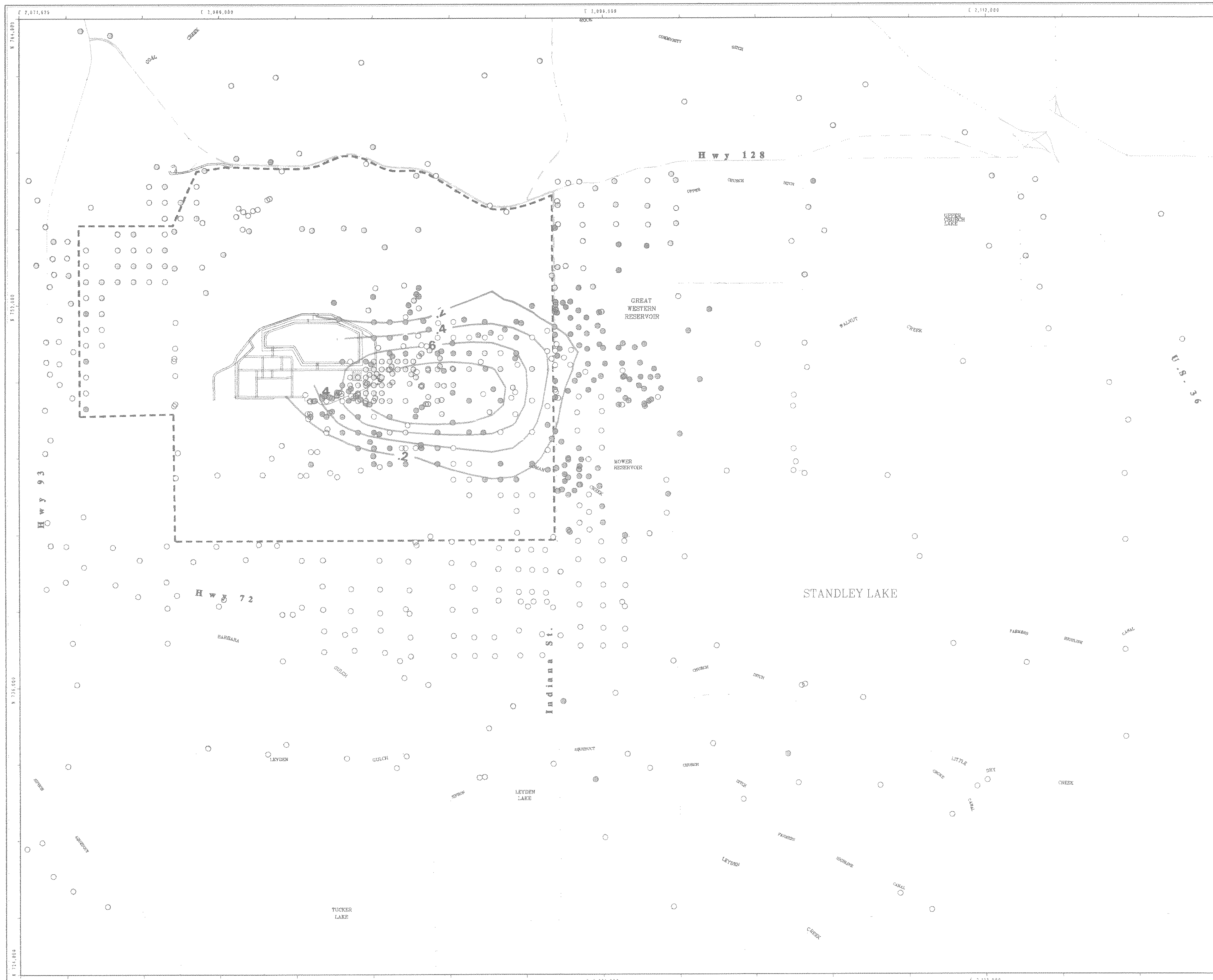
1900 0 2800 7600ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

MAP ID: Inced91

October 16, 1995

h:/r618888/air/cntr-out.aml


Hwy 128
Hwy 93
Hwy 72
U.S. 36
Indiana St.
STANDLEY LAKE
GREAT WESTERN RESERVOIR
MOWER RESERVOIR
UPPER CHURCH LAKE
LEYDEN LAKE
TUCKER LAKE
COAL CREEK
WALNUT CREEK
BARBARA GULCH
LEYDEN GULCH
LITTLE DRY CREEK
FARMERS HIGHLINE CANAL
2
4
6

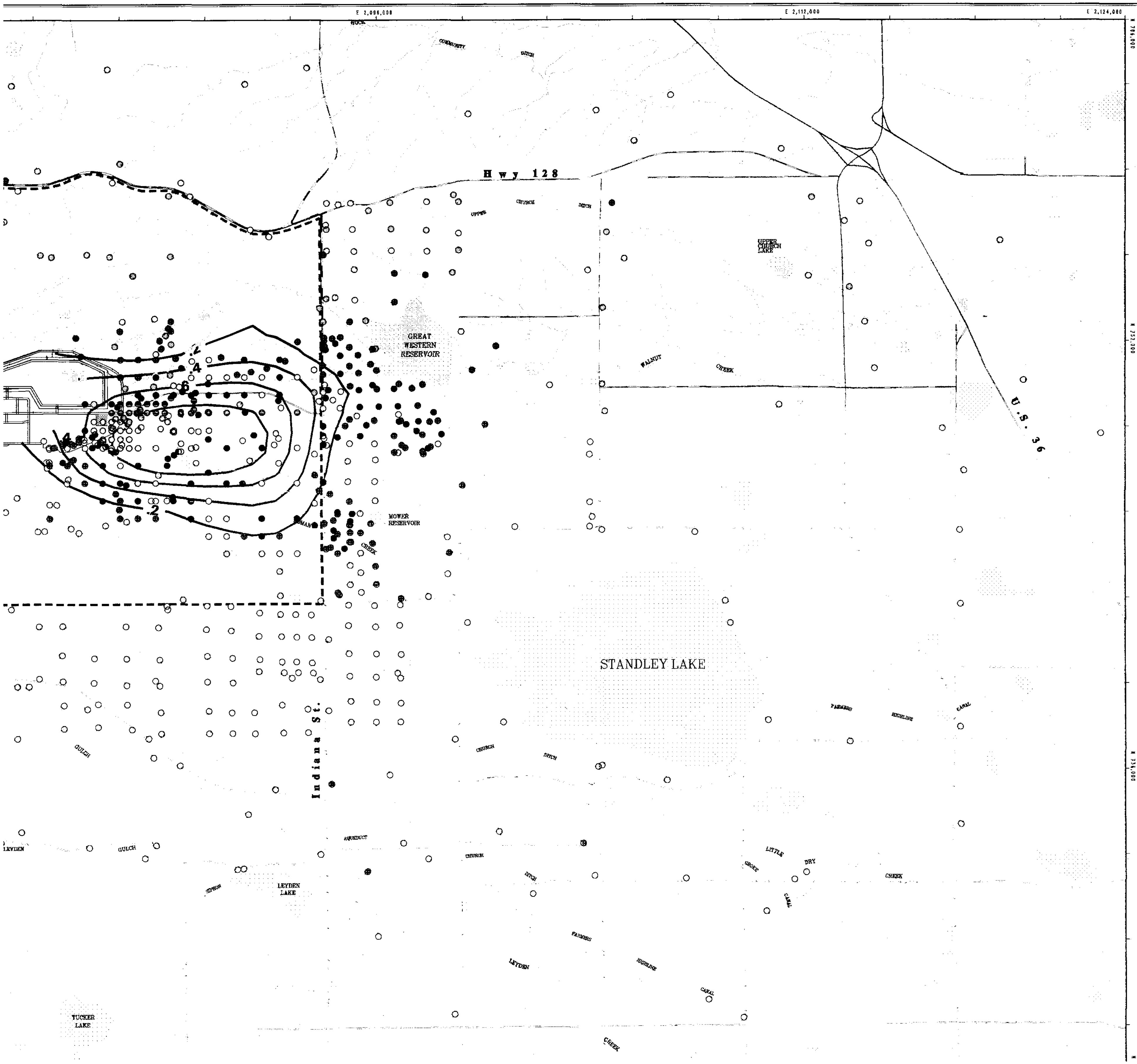


Figure 4-7A

Pu 239+240 Probability > 3.43 pci/g Isoplot with Exhaustive Surface Soil Sampling Locations
(E-Type Estimate)

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
U.S. Department of Energy

Concentration Levels (pci/g)

- < 0.08
- 0.08 - 0.29
- 0.30 - 0.89
- 0.90 - 1.99
- 2.00 - 4.99
- 5.00 - 9.99
- > 10.00

Standard Features

- Isoplot Lines
- 903 Pad
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats boundary
- Major Roads
- Secondary Roads
- RFETS Roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr. EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)

The contours for this map were created in Dynamic Graphics using a Kriged data file from M. Iggy Litaor, EG&G Geosciences - Jan. 1995.

Scale = 1 : 50400
1 inch represents 4200 feet

1900 0 3800 7600ft

State Plane Coordinate Projection
Colorado Central Zone

ous/ont-ramp.aml